THE KNOWLEDGE GROWTH REGIME. A SCHUMPETERIAN APPROACH

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PALGRAVE MACMILLAN, LONDON, 2018

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1. INTRODUCTION: THE ECONOMICS OF KNOWLEDGE FOR THE KNOWLEDGE ECONOMY

ABSTRACT

THIS INTRODUCTION PRESENTS THE ANALYTICAL FRAMEWORK IMPLEMENTED BY THE BOOK AS THE GRAFTING OF THE TOOLS ELABORATED BY THE ECONOMICS OF KNOWLEDGE AND THE LEGACY OF JOSEPH SCHUMPETER TO EXPLORE THE FOUNDATIONS OF THE NEW KNOWLEDGE ECONOMY AND THE SHIFT AWAY FROM THE CORPORATE GROWTH REGIME. IT FRAMES THE INNOVATION PROCESS AS A CREATIVE RESPONSE BASED UPON THE ACCUMULATION, GENERATION AND EXPLOITATION OF KNOWLEDGE AND HIGHLIGHTS THE NEW STRUCTURE OF ADVANCED ECONOMIES WHERE KNOWLEDGE IS AT THE SAME TIME THE PRIME INPUT AND OUTPUT. IT EMPHASISES THE LIMITS OF THE NEW KNOWLEDGE GROWTH REGIME, RAISED BY THE ROLE OF FINANCE, INCOME DISTRIBUTION AND INTELLECTUAL PROPERTY RIGHTS AND RECOMMENDS APPROPRIATE ECONOMIC POLICIES BASED UPON AN OPEN TECHNOLOGY APPROACH.

KEY WORDS: ECONOMICS OF KNOWLEDGE; KNOWLEDGE ECONOMY; SCHUMPETERIAN GROWTH REGIMES; OPEN TECHNOLOGY

The economic profession is reluctant to understand the aggregate and macroeconomic implications of the radical structural discontinuity brought about by the transition to the knowledge economy and the challenges raised by the central role of knowledge as an economic good. The decline of the industrial economy and the transition to the knowledge economy in advanced countries take place amid several difficulties. A major effort is necessary to understand this transition as a radical structural change that questions not only the working of the economy of advanced countries, but also the foundations of both economic analysis and economic policy (Kuznets, 1971).

Here the quote from the Obituary of John Maynard Keynes by Joseph Schumpeter seems most appropriate: "The social vision first revealed in the *Economic Consequences of the Peace*, the vision of an economic process in which investment opportunity flags and saving habits nevertheless persist, is theoretically implemented in the *General Theory of Employment, Interest, and Money* (Preface dated December 13, 1935) by means of three schedule concepts: the consumption function, the efficiency-of-capital function, and the liquidity-preference function. These together with the given wage-unit and the equally given quantity of money "determine" income and ipso facto employment (if and so far as the latter is uniquely determined by the former), the great dependent variables to be "explained." What a cordon bleu to make such a sauce out of such scanty material ……This permits many otherwise inadmissible simplifications: for instance, it permits treating employment as approximately proportional to income (output) so that the one is determined as soon as the other is. But it limits applicability of this analysis to a few years at most- perhaps the duration of the "40 months' cycle" -and, in terms of phenomena, to the factors that would govern the greater or smaller utilization of an industrial apparatus if the latter remains unchanged. All the phenomena incident to the creation and change in this apparatus, that is to say, the phenomena that dominate the capitalist processes, are thus excluded from consideration." (Schumpeter, 1946:510-512)

Schumpeter discussing the merit of the Marxian Doctrine acknowledged that: "As a matter of fact, capitalist economy is not and cannot be stationary. Nor is it merely expanding in a steady manner. It is incessantly being revolutionized *from within* by new enterprise, i.e., by the intrusion of new commodities or new methods of production or new commercial opportunities into the industrial structure as it exists at any moment. Any existing structures and all the conditions of doing business are always in a process of change. Every situation is being upset before it has had time to work itself out. Economic progress, in capitalist society, means turmoil. And, as we shall see in the next part, in this turmoil competition works in a manner completely different from the way it would work in a stationary process, however perfectly competitive. Possibilities of gains to be reaped by producing new things or by producing old things more cheaply are constantly materializing and calling for new investments. These new products and new methods compete with the old products and old methods not on equal terms but at a decisive advantage that may mean death to the latter. This is how “progress” comes about in capitalist society. In order to escape being undersold, *every* firm is in the end compelled to follow suit, to invest in its turn and, in order to be able to do so, to plow back part of its profits, i.e., to accumulate. Thus, everyone else accumulates.” Schumpeter (1942: 32)

The *Ecole de la regulation* has contributed much to exploring the dynamics of transformation as a process punctuated by radical technological and structural changes. According to Michel Aglietta: “The study of a movement, moreover, is the study of a change of state. If a system is described as dynamic, then the constitutive relationships of the system must have a logic of internal transformation. To conceive of the regulation of a system transforming itself in this way is to see the changes that occur in its relationship as such that these relationships can always be organized in to a system….There is no a priori reason why a transformation must be more than a ‘plastic transformation’ of the relationships that structure the system; if this were so, then continuity would be assured and reproduction would be simple. But when actual social systems are studies, historical experience confirms that transformation means rupture, qualitative change” (Aglietta, 1976/2000:12-13).

Schumpeterian scholars, as Freeman and Louca, exploring the long term transformation of advanced economies note that: "The structural transformation arising from these new industries, services, products and technologies is inevitably associated with the combination of organizational innovations needed to design, use, produce, and distribute them" (Freeman and Louçã, 2001:147).

All changes in the structure, organization, technology and knowledge governance are intertwined not only at the firm level, but also and primarily at the system level and reshape the entire architecture of interactions and transactions with major effects on both upward and downward complementarities (Dopfer et al., 2015).

The economics of knowledge provides the tools to analyze not only knowledge as a peculiar economic good but also the processes by means of which it is generated, accumulated and exploited. The advances of the economics of knowledge enable to implement a systematic investigation of the causes and consequences of the use of knowledge in society not only at the microeconomic level but also at the macroeconomic and meso level. The economics of knowledge is indispensable to grasp the working of the knowledge economy (Hayek, 1945; Arrow, 1962; Metcalfe, 2014).

The depth and width of the technological and structural changes that are occurring in advanced economies justify their analysis in a context of radical discontinuity that requires the understanding of the system dynamics at work. The identification of the stylized facts seems most useful to articulate an analytical framework that helps understanding it. The knowledge economy is characterized by the central role of the production and use of knowledge. Knowledge is both the central input and output of the economic activity. Knowledge based services constitute the bulk of both the demand and the supply. Not only final goods are more and more constituted by knowledge intensive services. Supply also is more and more based on knowledge intensive services that are used as intermediary inputs for the eventual production of all the other goods. Advanced countries specialize in the production of knowledge-based services as both capital and intermediary inputs and final goods that are imported from industrialized countries where the production of both capital and final goods takes place. Manufacturing industry declines sharply to about a 10% share of the economy while the share of Knowledge Intensive Business Services (KIBS) grow –often at a slower pace- towards the 10%. The traditional share of the manufacturing industry is replaced by the combination of advanced manufacturing cum KIBS (Antonelli and Fassio, 2014 and 2016).

The new knowledge economy is intrinsically light: the capital intensity of the production process of knowledge intensive business services is low and much lower than the capital intensity of the production processes of the manufacturing industries. The composition of capital also changes as the fixed component declines sharply and is partly compensated by the increase of the intensity of knowledge capitalized as an asset. The substitution of KIBS to the manufacturing industries affects the aggregate figures and triggers the reduction of the capital intensity at the aggregate level with effects in terms of the levels of investments and productivity.

The emergence of knowledge economy rests upon a bundle of distinct and yet highly intertwined processes: i) the globalization of product markets; ii) the globalization of financial markets; iii) the diffusion of new information and communication technologies (ICT); iv) the introduction of directed technological change biased towards the intensive use of locally abundant factors, i.e. in advanced countries, knowledge; v) the decline of the fixed capital intensity; vi) the apparent decline of output and productivity growth; vii) the increasing levels of income and wealth inequality; viii) the increasing privatization and capitalization of knowledge. Let us analyze them briefly in turn.

The globalization of international product markets has exposed advanced countries to the competition of new industrializing countries endowed with a large supply of cheap labor. The globalization of financial markets has increased the access of industrializing countries to a large supply of financial resources. The sequential combination of the globalization of product and financial markets has accelerated the emergence of the knowledge economy. Advanced countries discovered that their international competitive advantage could not rely any longer upon high levels of intensity of fixed capital. The international variance of availability and rental costs of capital declined rapidly. Industrializing countries could access and use financial resources at costs and conditions that quickly converged towards the –favorable- levels that were once available exclusively in advanced countries. The twin globalization of product and financial markets shook the foundations of the traditional division of labor undermining the competitive advantage based on high capital intensity and induced the introduction of biased technological change directed towards the intensive use of knowledge i.e. the production factor that emerged as relatively cheaper in advanced economies with respect to the rest of the globalized economy. Advanced countries experienced a dramatic shrinking of their manufacturing industry no longer able to compete with the efficient and highly (fixed) capital intensive supply by industrializing and industrial countries (Bloom, Draca, Van Reenen, 2016; Kogan et al., 2017).

The multinational growth of the large companies of advanced countries played a twin role in the process: i) it favored the rapid displacement of manufacturing industry towards industrializing countries enhancing the transfer of technological competence and favoring the export of their output to the domestic markets of advanced countries; ii) accelerated the pace to the knowledge economy with the 'headquarter effect' by means of which the knowledge intensive functions of the corporations based in the home countries became the hub of the new knowledge-based specialization of advanced countries.

ICT are the pillar of the knowledge economy. Their introduction and diffusion enabled the mobilization of and the interactive access to the large stock of quasi-public knowledge embedded in the economy of advanced countries. The systematic use of ICT enabled to increase the knowledge connectivity of the system reducing drastically knowledge absorption costs and favored the repeated use of knowledge as an input into the generation of new knowledge. ICT enabled the industrialization of the recombinant generation of new knowledge favoring the division of knowledge labor, the specialization and the participation of an increasing variety of agents embodied with different and yet complementary knowledge items to its generation, the opportunities for knowledge transactions and interactions in emerging knowledge markets and along user-producer interactions, with the eventual sharp increase in the efficiency of knowledge generation (Antonelli et al., 2000; Antonelli, 2017c).

The rich endowment of the knowledge stock, in terms of both size and variety, the high quality of the knowledge governance practices and the favorable conditions of its access and use, based upon respectively upon the limited exhaustibility of knowledge and its limited appropriability, provided advanced economies with the opportunity to implement a new specialization based on the intensive use of knowledge as a key good that is at the same time an input and an output. The competitive advantage of advanced countries could rely upon the low comparative costs of knowledge that supported the fast introduction of directed technological change biased towards the intensive use of knowledge.

The capability of industrializing countries to accumulate and access the stock of quasi-public knowledge that characterizes the advanced countries is in fact much lower. The Leontieff paradox experienced by the US economy, well before the globalization of financial markets, generalized to the rest of advanced countries. The specialization of rich, capital abundant countries, in skill intensive activities with high levels of knowledge content, experienced by the US as the leading country in the international innovation race, spread to the countries that the twin globalization eventually exposed to the erosion of the traditional foundations of their competitive advantage based upon the relative abundance of capital (Antonelli and Fassio, 2011; Antonelli and Colombelli, 2011b).

The fast globalization of product and financial markets under way since the end of the 20°century has been affecting in depth labor markets. The dynamics of factor costs equalization triggers in fact the decline of industrial wages and employment in capital abundant countries, together with their increase in labor abundant ones. The introduction of new technologies however can change the direction of the process as long as it is able to expand the frontier of possible outputs in capital abundant countries and contrast the fall of wages.

When and if, technological change is directed, however, the change of the frontier does not take place as a radial expansion that affects equally all the output combinations, and concentrates upon activities characterized by high barriers to entry and specific job requirements, the dynamics of factor costs equalization triggers the segmentation of labor markets. Standard labor employed in the manufacturing industries is fully exposed to the decline of wages and of job opportunities with increasing levels of unemployment. In the markets for skilled and creative workers, instead, wages are resilient at pre-globalization levels and and job opportunities increase.

The organization of the generation and exploitation of knowledge has experienced radical transformations in the last decades. The vertical integration of knowledge generation activities within large corporations has been progressively substituted by venture capitalism and the emergence of a knowledge industry specializing both in the provision of KIBS and in the generation of knowledge capital. Corporations outsource the generation of knowledge and rely more and more on both specialized suppliers of knowledge intensive services and the acquisition of high tech start-ups in financial markets.

The generation and use of knowledge as the key input and output of advanced economies seems characterized by high levels of: i) skilled labor intensity and low levels of fixed capital intensity; ii) high frequency of interactions: not only vertical interactions between bottom-up learning processes that enable the accumulation of competence and top-down technological applications of scientific knowledge, and between users and producers, but also horizontal between public and academic research and small high-tech start-ups sponsored by venture capitalism. The knowledge economy relies upon the intensity of recombination of the variety of knowledge items held by each unit in the system.

The path to towards the knowledge economy based upon the central economic role of knowledge has major structural implications for advanced economies:
i) The shift away from an industrial economy based upon a strong manufacturing industry in terms of sectoral composition of the economy, with the decline of the manufacturing industry and the rise of the knowledge intensive business services. The share of employment in the manufacturing industry of advanced countries started its decline since the late years of the XX century. In UK it declined from the 15.7% of 1995 to 9.6% in 2007, in France in the same time interval from 15.0% to 11.5%, in the Netherlands from 12.9% to 9.6%. The crisis of 2007 had only marginal effects on the process: in UK the share of employment in manufacturing in 2014 dropped to 8.1%, in France to 9.9%, in the Netherlands to 8.8%. The share of manufacturing in investments drops even more sharply in the same time interval. In the UK it drops from 11.6% in 1996 to 5.6% in 2007 and 6.2% in 2014, in France from 10.8% to 7.2% in 2007 to 6.9% in 2014, in the Netherlands from 9.8% in 1995 to 5.8 in 2007 to 5.9% in 2013;
ii) The increasing role of KIBS substitutes and complements the smaller manufacturing industry. The vertical disintegration of the generation of knowledge and the emergence of a knowledge industry at the core of the KIBS has major implications at the system level in terms of faster rates of

generation of technological knowledge and hence introduction of innovations.

The strong increase of the share of intangible assets in the total asset value of the S&P 500 firms from the 16.8% of 1975 to 79.70% in 2005 (Pagano and Rossi, 2009) can be considered, *coeteris paribus* the relative inputs price, a reliable clue of the strong bias of technological change directed towards the introduction of knowledge intensive and fixed capital saving technologies.

After two decades from its preliminary emergence, the transition to the knowledge economy reveals to be more problematic than expected. The demise of the Fordist model takes place among delays and negative reactions. The radical decline of the manufacturing industry as the heart of the economy engenders major problems in labor markets with strong mismatches between demand and supply in terms of skills and competences. The intensive dynamics of factor costs equalization, stemming from the strong competition in global product markets raised by low-wage, labor abundant large economies, triggers, in advanced countries the sharp decline of the wage levels of standard labor that coupled to labor markets rigidities leads to the persistent exclusion from the labor markets of a large share of former manufacturing workers with low opportunities for reskilling and to a significant increase of long-term unemployment. At the same time the supply of creative manpower able to participate in the growth of KIBS is scarce because of relevant barriers to entry and mobility, with significant effects on income levels where wages are augmented by the participation to the wealth generated by knowledge. The segmentation of the labor markets and the raising levels of wage and rent inequality are the consequence of the increasing role of the new mechanisms of generation and exploitation of knowledge. The rates of growth of output and productivity in the knowledge intensive sectors parallel the systematic decline of aggregate output and productivity growth triggered by the decline of manufacturing sectors and increasing levels of inequality in the distribution of income and wealth.

This book elaborates the hypothesis that this aggregate dynamics are the consequence of the radical structural change that is taking place within advanced economics with the transformation from industrial into knowledge economics, stirred by the fast globalization of product and capital markets, the identification of a new specialization based upon the generation and exploitation of knowledge and the segmentation of labor markets with important effects in terms of increasing levels of wage, rent and income inequality. A growing and yet unequal knowledge economy is emerging as the core of advanced economic systems.

This interpretation contrasts the hypothesis that advanced countries are experiencing a secular stagnation brought about by the decline of the rates of technological change (Cowen, 2011; Piketty, 2014; Summers, 2014; Mazzucato and Jacobs, 2016; Gordon, 2016; Franzini, Pianta, 2016; Bloom et al.,2017). The rest of the book elaborates the hypothesis that a radical structural change is taking place. The hypotheses about the secular stagnation of advanced economies recently and the decline of the productivity of research activities seem to be influenced by the poor appreciation of the role of knowledge not only as a capital (intangible) input, but also as a capitalized output.

The notion of Schumpeterian growth regime becomes necessary to understand the structural transformation of advanced economies. The discontinuity experienced by advanced economies since the last decade of the XX century can be fruitfully analyzed as the consequence of the shift from a mode of organizing the generation, exploitation and accumulation of knowledge centered upon the industrial corporation to a new mode based upon a specialized knowledge industry.

Schumpeterian growth regimes are identified by the alternative sets of systemic conditions and coordination modes at the microeconomic, mesoeconomic, macroeconomic and institutional levels that shape both the out-of-equilibrium conditions that stir the reaction of firms, the size and variety of the stock of knowledge embedded in the system, and the quality of the systemic mechanisms of knowledge governance that support the generation, exploitation, appropriation and accumulation of knowledge and the generation of the endogenous knowledge externalities upon which the creative response and the consequent introduction of innovation is contingent (Antonelli, 2017a, 2018c).

The integration of the recent advances of the economics of knowledge with the Schumpeterian legacy enables to elaborate and apply the notion of Schumpeterian Growth Regime to understand how the structure of the system shapes the mechanisms of generation, appropriation, exploitation and accumulation of knowledge that in turn shape the creative response of firms, that changes product and factor markets, the structural characteristics of the system and its macroeconomic performances.

According to the Schumpeterian framework of analysis of the creative response, in fact, firms try and innovate to cope with emerging mismatches between expected and actual factor and product market conditions (Schumpeter, 1947). Technological knowledge is the key factor of the innovative activity of an economic system. The chances that firms can implement a creative response that supports the rate of introduction of innovations depends upon their learning capabilities and the levels of pecuniary knowledge externalities i.e. upon the conditions at which they can access and use technological knowledge in order to cope with the mismatches between expected and actual product and factor market conditions.

When the structural and institutional conditions of the system make the generation of new knowledge too expensive, firms can only implement adaptive responses and move on the map of existing isoquants. When, instead, the size and variety of the stock of knowledge is large and the structural and institutional conditions of the economic system, including its mechanisms of knowledge and learning governance, enable the access and its use at low costs and, consequently, pecuniary knowledge externalities are large, firms are able to implement a creative reaction and introduce innovations.

The process may exhibit strong elements of path dependent complexity: at each point in time the lower is the cost of knowledge and the larger the chances that the creative response of firms takes place. In this case firms in order to introduce innovations, generate additional flows of technological knowledge that add to the stock of quasi-public knowledge that -because of its limited exhaustibility and appropriability- under the condition that the quality of the knowledge governance mechanisms at work in the system do not decline, can be accessed and used at lower costs. The introduction of innovations triggers new out-of-equilibrium conditions in both product and factor markets that in turn stir the response of firms. Because of the increased size and variety of the stock of quasi-public knowledge, augmented by the flows of new knowledge, for given quality of the knowledge governance mechanism, pecuniary knowledge externalities are larger and the chances that the response of firms, at time t+1, is larger, are stronger. A virtuous loop of positive feedbacks, based upon the limited exhaustibility and appropriability of knowledge that trigger pecuaniry extrernalities, can last until the quality of knowledge governance mechanisms does not decay.

Productivity growth and hence economic growth is possible only when and if the potentialities for dynamic increasing returns, intrinsic to the idiosyncratic characteristics of knowledge and especially its limited exhaustibility, cumulability and extensibility, are exploited (Antonelli, 2017a and 2018c).

The properties of knowledge as an economic good, and specifically its limited appropriability, exhaustibility and tradability and the idiosyncratic, systemic and contingent conditions and characteristics of the mechanisms that implement its generation, use and exploitation qualify the Schumpeterian growth regimes and are key to grasping the ultimate determinants of growth and change.

The new knowledge economy can be regarded as the new emerging Schumpeterian regime based upon a new mode of organizing the generation, exploitation and accumulation of knowledge elaborated by advanced economies to take advantage of the competitive advantage provided by their unique endowment of a large stock of knowledge accumulated through time because of its limited exhaustibility. The knowledge economy of advanced economics is based upon the unique conditions to accessing and using the stock of knowledge as an input and is specialized in the provision of knowledge flows generated by the new emerging knowledge industries to the rest of the world economy.

The radical structural change based upon the shift away from manufacturing industry and the specialization in the generation and use of knowledge has a strong impact on the whole range of economic activities. Intangible investments become the central driver of production. Tangible investments consist in the actual purchase of physical capital goods that are being produced by an array of specialized industries. Intangible investments are but the capitalization of the expenditures consisting mainly if not exclusively of creative labor costs and their knowledge output. On the output side knowledge as a financial asset is becoming one of the main products of economic activity. Yet, in the current accounting procedures, it is not recorded as such: it leads directly to the increase of wealth rather than value added.

These changes are not properly reflected by the current accounting methodologies. The capitalization of knowledge is the cause of a specific and poorly investigated mis-measurement problems that do not stem from the problems associated with the prices of high tech product but with the correct appreciation of the role of the capitalized knowledge not only as an input, but also as an output in national accounts (Byrne, Fernald, Reinsdorf, 2016).

The increase of intangible capital stock as an input in fact does not parallel the inclusion on the output side of the increasing amount of wealth generated by the capitalization of knowledge. Accounting methodologies, are more and more able to take into accounts the changing mix of inputs in the production function that is shifting away from the traditional mix of two fundamental inputs -the stock of machines and labor- to a mix of three basic factors: tangible capital goods, labor and the stock of knowledge capital. On the output side, however, although the increasing amount of knowledge, capitalized as a financial asset, plays an increasing role, accounting methodologies have not yet made the necessary progress in handling the new role of intangible outputs.

The consolidation of the knowledge growth regime as the new institutional base of advanced countries and the evidence about their radical transformation with the demise of the corporate growth regime and the parallel collapse of the middle class call for a political economy approach able to stretch the scope of investigation of the economics of knowledge to enquire about the new emerging social organization of the knowledge growth regime (Jones, 2002).

The command of the economics of knowledge and the stretching of its heuristics to the analysis at the system level enables to understand the mechanisms that are at the heart of the transformation of the old industrial economies into knowledge economies. The notion of Schumpeterian Growth Regimes is indispensable to grasp the depth of this structural change into the knowledge economy as it enables to grasp the central role of knowledge as the engine of growth and the changing mechanisms of knowledge governance.

The analysis of the generation of technological knowledge as a recombinant process based upon the stock of non-exhaustible knowledge, cumulated through time, and its shift from the corporation to the new knowledge industries calls attention on the increasing levels of income inequality. The new mechanisms of exploitation of knowledge are associated with increasing levels of wage and rent inequalities. Creative workers able to generate and appropriate new technological knowledge can enjoy resilient wages and income share augmented by their direct participation to the rent associate to the capitalization of knowledge. The wages and employment levels of standard labor are doomed to a systematic decline driven by the dynamics of factor costs equalization triggered by the entry in the globalizing product markets of the exports from low-wage and labor abundant large economies.

At the same time, it is clear that the strong exclusivity of the current intellectual property right (IPR) regime limits the width and the depth of the recombinant process upon which the generation of new knowledge rests. The identification of an appropriability trade-off between the need to secure appropriate levels of incentives to the generation of technological knowledge and the need to extend its accessibility in order to reduce the cost of knowledge recombination, requires new solutions.

The knowledge economy seems more and more trapped by the contradictions of the appropriability trade-off. The positive consequences of the limited appropriability and exhaustibility of knowledge seem larger than its negative ones in terms of reduced incentives. The negative effects of anticommons are becoming more and more apparent together with the increasing role of knowledge as the central input and output of the new economic system.

These processes call attention on the need to shape a new knowledge policy that is able to overcome the limits of the knowledge economy in terms of increasing income inequality and excess exclusivity of IPR. The results of the Schumpeterian analysis of the knowledge economy have strong implications to advocate a new knowledge policy based upon not only on Open Science, but also on Open Technology. A new knowledge policy should be based upon the reduction of the exclusivity of knowledge ownership augmented by the current (IPR) regime (Posner, 2005; Stiglitz, 2008) and the incentives to increase the rates of accumulation of knowledge.

In this context it seems more and more important to contrast the trends towards the increased privatization of IPR. The enforcement in March 1994 of the Agreement of Trade-related Aspects of Intellectual Property Rights (TRIPs Agreement) and the recent US patent reform led to the strengthening of IPR and their globalization. This enhanced privatization of knowledge can be regarded as one of the main institutional changes that characterize the new knowledge economy. Many have compared the current trends towards the reinforcement and extension of IPR to the enclosure of common land that preceded and actually enabled the Industrial Revolution (Gallini, 2002; Pagano, 2014; Pagano Rossi, 2009; Aghion, Howitt, Prantl, 2015).

While land enclosures had positive effects on economic growth, knowledge enclosures risk to undermine the basis of growth. The enclosure of knowledge on the one hand strengthens the market power of the specialized suppliers of knowledge, but on the other reduces the access to the stock of existing knowledge and hence curbs the rate of the recombinant generation of new knowledge and increases dramatically the market price of knowledge for downstream users. The viability of the knowledge growth regime rests upon the quality of knowledge governance mechanisms based upon the fine tuning of the appropriability trade-off, the appreciation of the role of the limited exhaustibility of knowledge and new mechanism of social and economic inclusion that limit its intrinsic exclusivity.

The rest of the book is organized as it follows. Chapter 2 presents the achievements of the economics of knowledge showing the rich implications for macroeconomic analysis of its microeconomic foundations. Chapter 3 provides a unifying framework that integrates the Schumpeterian creative response and the localized technological change approaches stressing the central role of knowledge and explores its implications to grasping the knowledge intensive direction of technological change and the capitalization of knowledge. Chapter 4 presents the notion of Schumpeterian Growth Regimes with special attention to the evolution from the entrepreneurial growth regime to the corporate growth regime and finally to the knowledge growth regime. Chapter 5 presents a political economy approach to the knowledge growth regime. Chapter 6 elaborates the foundations for a new knowledge policy, indispensable to cope with the intrinsic weaknesses of the knowledge growth regime, based upon the introduction of non-exclusive IPR that implement the role of knowledge as an essential facility in an Open Technology approach. The conclusions summarize the main results of the analysis stressing the role of the economics of knowledge to understand the foundations and the working of the knowledge economy.

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2.THE ECONOMICS OF KNOWLEDGE

ABSTRACT. THIS CHAPTER SUMMARIZES THE MAIN ACHIEVEMENTS OF THE ECONOMICS OF KNOWLEDGE WITH SPECIAL ATTENTION TO THE CENTRAL ROLE OF THE LIMITED EXHAUSTIBILITY OF KNOWLEDGE AND ITS IMPLICATIONS IN TERMS OF CUMULABILITY AND EXTENSIBILITY. IT RECALLS THE EARLY ECONOMICS OF KNOWLEDGE. IT EXPLORES THE GENERATION AND EXPLOITATION OF KNOWLEDGE WITH THE TECHNOLOGY PRODUCTION FUNCTION AND THE KNOWLEDGE GENERATION FUNCTION. IT ELABORATES THE KNOWLEDGE APPROPRIABILITY TRADE-OFF, ANALYSES THE PROBLEMS OF THE PROVISION OF FUNDS TO INNOVATION, HIGHLIGHTS THE RELATIONSHIPS BETWEEN KNOWLEDGE EXTERNALITIES AND TOTAL FACTOR PRODUCTIVITY STRESSING THE NEW TRENDS TOWARDS THE CAPITALIZATION OF KNOWLEDGE AS A FINANCIAL ASSET.

KEY WORDS: LIMITED APPROPRIABILITY OF KNOWLEDGE; LIMITED EXHAUSTIBILITY OF KNOWLEDGE; KNOWLEDGE ACCUMULATION; KNOWLEDGE GENERATION AND EXPLOITATION; KNOWLEDGE AND IMITATION EXTERNALITIES; TECHNOLOGY PRODUCTION FUNCTION; KNOWLEDGE GENERATION FUCNTION; GENERAL INTELLECT.

2.1 INTRODUCTION

Knowledge is the primary economic good: it differs however from ordinary economic goods as it is characterized by specific and highly idiosyncratic properties such as its limited appropriability, exhaustibility and tradability, that stress the central role of the systemic and contingent conditions that shape its generation, use and exploitation and qualify the Schumpeterian growth regimes as they are key to grasping the ultimate determinants of growth and change.

The emergence and consolidation in advanced countries of the knowledge economy makes the analysis of knowledge as an economic good especially relevant. The economics of knowledge has developed a rich set of tools that now allow us to deepen the study of the mechanisms of generation, use and exploitation of knowledge, both at the micro and the meso level and to understand the working of the knowledge economy at large (Antonelli and David, 2015; Antonelli and Link, 2015).

The microeconomics of knowledge has made major progresses so as to provide an articulated and inclusive framework that enables to grasp the determinants of the growth of firms. The achievements of the microeconomics of knowledge are so relevant that they deserve to be applied as a tool of investigation to grasp the dynamics of economic systems at the meso and macro level.

The microeconomics of knowledge has provided the foundations to articulate the hypothesis that knowledge in highly specific and qualified conditions is the primary source of total factor productivity growth. The appreciation of the limited exhaustibility of knowledge, next to its limited appropriability, has in fact provided the foundations of a new understanding of the working of the system at the aggregate level based upon the accumulation and eventual access to knowledge stocks.

The rest of this chapter recalls the key steps of the advances of the microeconomics of knowledge from the focus on the limited appropriability of knowledge to the discovery of its limited exhaustibility and explores its implications for economic analysis and policy at the aggregate level.

2.2 THE EARLY ECONOMICS OF KNOWLEDGE

The early microeconomics of knowledge was based upon the analysis of the economic properties of knowledge as an economic good introduced by Kenneth Arrow (1962a and 1969). According to Nelson (1959) and Arrow (1962a) knowledge is an economic good characterized by intrinsic low levels of appropriability and excludability. Negligible reproduction costs compared to high generation costs worsen the risks of uncontrolled leakage and reduce the opportunity for inventors to take advantage of their inventions.

In its first stage the economics of knowledge focused the attention on the negative consequences of the idiosyncratic characteristics of the low levels of knowledge appropriability in terms of the market failure stemming from the limited incentives to its production and the poor division of labor stemming from its limited tradability.

Limited knowledge appropriability and excludability has been long regarded as a cause of market failure and undersupply of knowledge. The knowledge market failure stems from two distinct and yet interrelated consequences of the idiosyncratic characteristics of knowledge. Let us consider them in turn.

First, knowledge cannot be traded as such. The market exchange of knowledge is dramatically limited by the risks of opportunistic behavior ex-ante by the perspective seller and ex-post by the perspective customer. The perspective customer wants to limit the risks of opportunistic conduct of the perspective seller and has strong reasons to request the inspection of the new knowledge in order to verify its actual content and minimize the risks of purchasing a “lemon”. As soon as the perspective vendor, however, accepts to reveal the actual content of the knowledge, s/he bears the risk that the perspective customer may walk away and use it without any payment. The intrinsic information asymmetry impedes the trade of knowledge as a stand-alone economic good. Knowledge can be traded only if it is embodied in other economic goods.

Second, the leakage of knowledge cannot be prevented and competitors can take ‘opportunistic’ advantage of the knowledge generated by third parties. Imitative entry takes place immediately after the introduction of the innovation and triggers the fall of its prices. Even research expenditures cannot be expensed: prices fall to the levels of the costs of the capital, labor and other intermediary inputs. Consequently, even successful and fertile research activities are characterized by substantial uncertainty in terms of actual economic returns. The risks associate to its appropriability limit their scope to research projects with very high levels of expected yields.

High risks in the actual delivery of the expected research outcome and high risks on the actual possibility to extract revenue out of the expected output hinder the provision of financial resource to fund research activities. Only firms that can take advantage of existing barriers to entry and enjoy extraprofits that can be retained rather than distributed to shareholders can fund research activities as barriers to entry act as barriers to imitation.

The two arguments complement each other and suggest that economic systems cannot rely on the market place as a reliable mechanism to provide the correct allocation of resources to the generation of new knowledge. Public policy is indispensable to remedy the knowledge market failure (Arrow and Lind, 1970).

The intuition by Zvi Griliches (1979, 1986, 1995, 1998) about the positive effects of the limited appropriability of knowledge in terms of spillover and knowledge externalities contributed to articulate the Arrovian knowledge market failure argument. The analysis of the positive effects of the knowledge spilling to third parties has revealed the hidden side of the knowledge non-appropriability and excludability.

The eventual introduction of the "technology production function" where knowledge spillovers enter as important inputs in turn provided the basic tools of the new growth theory. The new growth theory provided the framework to understand at the macroeconomic level the implications for economic growth of the role of knowledge as a central production factor.

The new growth theory has been built upon the notion of knowledge spillover assuming that 'inventors' can appropriate only a part of the benefits generated by the introduction of new knowledge, while the system at large can benefit of the non-appropriable part so as to generate total factor productivity growth. The new growth theory assumes that the output elasticity of knowledge is so large that it can be split in private and social returns and yet the former is sufficient to induce firms to fund research activities that yield "equilibrium" returns plus social returns accounted as residual. The availability of the non-excludable portion of knowledge, as a public good, accounts for total factor productivity growth.

In the new growth theory, like in Arrow, the amount of knowledge used is lower than in equilibrium but its total output (the sum of private and social returns) is larger than in equilibrium. The total marginal product of knowledge lies above the private one. For a given knowledge cost the "equilibrium" amount of knowledge selected by private investors is lower that it would have been if they could appropriate all the returns. At the same time, however, the sum of both private and social returns is larger: the social returns are accounted as residual (Romer, 1990 and 1994; Link and Siegel, 2007; Hall, Mairesse, Mohnen, 2010).

The new growth theory paves the way to appreciating the role of the economics of knowledge to understand the working of the system at large and its dynamics well beyond the boundaries of its microeconomic origins. The appreciation of the role of knowledge spillover in terms of total factor productivity at the system level, however, raises new questions and new issues.

First, the new growth theory does not provide a satisfactory analysis of the determinants of the share of revenue triggered by the use of knowledge that can be appropriated by "inventors" and the part that, spilling in the atmosphere, contributes total factor productivity. The determinants of its -large- variance across time, firms, industries, regions and countries are poorly investigated.

Second, and most important, the new growth theory unveils the mismatch between the theory of production and the theory of income distribution. The contribution of the stock of knowledge to output is larger than its share of revenue. The share of output triggered by the fraction of the output elasticity of the stock of technological knowledge that spills and is not appropriated is, in fact, accounted as the residual. As such it is paid to all production factors. The new growth theory implies that the Euler's theorem according to which the share of revenue paid to each factor equals its output elasticity does not apply. The new growth theory is a theory of out-of-equilibrium income distribution. The Arrovian knowledge undersupply is now twisted to a theory of knowledge underpayment (Romer, 1990, 1994, 2015).

The analysis, implemented through this book, impinges upon the exploration of the generation of knowledge and of the cost of knowledge, the role of absorption, access and use of the knowledge spilling in the system and shifts the focus from technical to pecuniary knowledge externalities to provide an analytical framework that can implement the results of the new growth theory. The actual justification for excess returns and the related growth of output and total factor productivity is found only when the limited exhaustibility of knowledge is taken into account together with its limited appropriability both in the generation, accumulation and exploitation of knowledge. Spillovers engender excess returns because third parties can use *again* knowledge, that has been generated, introduced, used and –partly- exploited by "inventors", at cost that are below equilibrium levels. The limited exhaustibility of knowledge is the actual determinant of the positive sum game that is accounted by new growth theory.

2.3 THE KNOWLEDGE GENERATION FUNCTION

The economics of knowledge is shifting attention from the analysis of the use of knowledge as an input into the technology production function to the analysis of the mechanisms and processes by means of which knowledge is generated, exploited and valorized. The knowledge generation function is the new frontier of the economics of knowledge.

The advances of the economics of knowledge have progressively made clear that knowledge is at the same time an input and an output. The knowledge used as an input in the production of all the other goods is itself the output of a dedicated activity and an indispensable input, not only for the introduction of an innovation, but also for the generation of further knowledge (David, 1993).

Building upon the Schumpeterian (1934) intuition that the generation of new knowledge is the result of the 'creative recombination of existing knowledge', Weitzman (1996) enriched the analysis of the knowledge generation function highlighting its recombinant character: existing knowledge items are indispensable for the generation of new technological knowledge. Its generation consists in the recombination of existing knowledge items that enter the process as inputs in a recursive process (Arthur, 2007). Fleming and Sorenson (2001) suggest that the generation of technological knowledge follows a branching process where the new modules stand upon the old ones.

The generation of knowledge acquires the typical traits of a non-ergodic path dependent process where indeed the present is influenced, at each point in time, by the past, but contingent events can change both its direction and rate. This approach has important implication: i) the stock of knowledge that entered the technology production function, now enters the knowledge generation function: in both cases it is an indispensable input (Fleming, 2001); ii) the size, variety and accessibility of the existing stock of knowledge changes with the recursive accumulation of the new vintages of knowledge; iii) the selective availability of existing knowledge shapes the direction and the rate of the generation of new knowledge; iv) the larger is the portfolio of existing and accessible knowledge modules and the larger is the productivity of the knowledge generation process. The wider is the inclusion of existing knowledge items in the recombinant knowledge generation process and the larger the output (Weitzman, 1996).

As Arthur notes: “I realized that new technologies were not ‘inventions’ that came from nowhere. All the examples I was looking at were created-constructed, put together, assembled-from previously existing technologies. Technologies in other words consisted of other technologies, they arose as combinations of other technologies” (Arthur, 2009: 2).

The analysis of the generation and use of knowledge enables to identify three distinct layers: i) the stock of knowledge at time t-1 is a necessary input into the generation of new knowledge. The stock of pre-existing knowledge is in fact the object of the recombination that leads to the eventual generation of new knowledge; ii) at each point in time the flow of knowledge is the output of a dedicated economic activity, that is the knowledge generation function; iii) at each point in time the stock of knowledge -augmented by the flows that have been generated at that time- is an indispensable input in the technology production function, i.e. in the production of all the other goods.

The appreciation of the recombinant character of the generation of knowledge enables to identify and highlight the crucial role of the limited exhaustibility of knowledge in the accumulation of stocks of knowledge.

All the knowledge generated contributes the stock of knowledge including the proprietary knowledge internal to each firm. Its limited appropriability allows the use of all the stock by third parties. Its access and use, however, are not free: substantial search and absorption activities are necessary even for the proprietary component. At each point in time the stock of knowledge must be retrieved and applied: such activities are carried out by creative workers at a cost.

Both the size and the variety of the stock of knowledge play an important role to support the generation of new technological knowledge and its effects in the production of all the other goods. Not only the size matters: the wider is the variety of types of knowledge that compose the stock of quasi-public knowledge and the stringer the externalities that benefit the agents in the system (Antonelli et al., 2017). The larger is the stock of knowledge and the wider its variety and the lower the costs of accessing and using it.

For a given size and variety of the stock of knowledge, the quality of the knowledge governance mechanisms at work in the system are determinant in the identification of the actual level of the cost of accessing and using it. The stock of knowledge can be regarded as a quasi-public good. The access to knowledge stocks in turn yields long lasting effects in term of growth of output and total factor productivity and rents.

Following Griliches (1979; 1984: 1986; 1992) and Weitzman (1996), a system of the equations, that includes the technology production function and the knowledge generation function, enables to formalize the analysis implemented so far. The inputs of the knowledge generation function are: i) the current R&D expenditures, ii) the quasi-public stock of quasi-public knowledge. The knowledge generation function, in the standard c.r.s. Cobb-Douglas specification, and the knowledge cost equation are:

(1) $KN = R\&D^{d}\, TK_{(t-1)}^{1-d}$

(2) $TC_{KN} = zR\&D + vTK_{(t-1)}$

where KN stands for the flow of knowledge output, R&D for internal research and learning activities, TK, for the stock of quasi-public knowledge (at time t-1) and d measures the output elasticity of R&D. Both R&D and TK have a cost. The cost z measures the costs of research activities; the cost v measures the absorption of and access costs to the stock of quasi-public knowledge.

We assume that TK, the stock of all the existing knowledge generated until that time, is a complementary, indispensable input into the generation of new knowledge. Its use is not free: it can take place at a specific cost v that accounts for the wide range of activities that are necessary to absorb and use it (Cohen and Levinthal, 1989 and 1990).

The flow of knowledge (KN) generated at each point in time contributes the technology production function:

(3) $Y = K^a L^b TK^c$

where Y measures output in value added, K measures the stock of capital, L labor and TK the stock of knowledge capital; a, b, c measure the output elasticity of the inputs.

The cost equation is standard:

(4) $TC_Y = wL + rK + sTK$

where w is the cost of labor, r the cost of capital and s the cost of knowledge.

The flow of knowledge generated at each point in time by the knowledge generation function adds to the stock of knowledge that enters the technology production function, after taking into account the -low- rate of depreciation and obsolescence (δ):

(5) $TK\text{-}TK_{(t-1)}(\delta) = KN$, for $0 < \delta > 1$.

Positive pecuniary knowledge externalities are found when v and s, the costs of accessing and using the stock of knowledge, are below equilibrium levels. When the cost knowledge falls below equilibrium levels the creative response of firms can take place. The creative response triggers a cascade of positive feedbacks: i) new technological knowledge is generated, 2) the stock of technological knowledge available in the system increases, 3) innovations are being introduced, 4) total factor productivity and output increase; 5) new out-of-equilibrium conditions in product and factor markets emerge.

The stock of knowledge, however, resides exclusively in the brain of human beings. Knowledge consists of creative labor and cannot be separated from it. Any quantity of books, patents, blueprints exists and performs an economic function only if it is embedded in and commanded by human labor able to use and implement it. Without human labor it disappears into libraries and repositories with no economic value. Human labor is necessary to remember the stock of knowledge, to apply it, and to use it to generate new knowledge bioth in the knowledge generation function and in the technology production function. Knowledge coincides with the skills and competencies of human labor able to memorize and use the stock of knowledge: creative labor has distinctive qualifications that distinguish it from standard labor.

Here the Marxian notion of “general intellect” becomes relevant: "Nature builds no machines, no locomotives, railways, electric telegraphs, self-acting mules etc. These are products of human industry; natural material transformed into organs of the human will over nature, or of human participation in nature. They are organs of the human brain, created by the human hand; the power of knowledge, objectified. The development of fixed capital indicates to what degree generalsocial knowledge has become a direct force of production, and to what degree, hence, the conditions of the process of social life itself have come under the control of the general intellect and been transformed in accordance with it; to what degree the powers of social production social have been produced, not only in the form of knowledge, but also as immediate organs of social practice, of the real life process." (Marx (1857-8/1974:706).

The central role of the stock of quasi-public knowledge both in the technology production function and in the knowledge generation function calls attention on the indispensable role of creative labor to produce both all the other goods and new knowledge itself. Knowledge is an activity rather than a good and it is intrinsically collective (Antonelli, 2000).

2.4 THE EXHAUSTIBILITY OF KNOWLEDGE

The economic literature has little investigated the broader economic effects of the limited exhaustibility of knowledge as an economic good far lower with respect to standard economic goods. Attention has been focused on non-excludability, the first key characteristic of public goods. Yet its application to knowledge implies necessarily the identification and appreciation of the role, not only of its limited appropriability, but also of its limited exhaustibility

So far, the economic literature has grasped only some of the important effects of the limited exhaustibility of knowledge identifying the role of extensibility and cumulability.

Knowledge extensibility is the primary source of economies of density. The very same knowledge item can be applied repeatedly as an input into the production of a good without limitations. When the –fixed- cost of the given knowledge item can be spread on increasing units of output, average cost decline. The exploitation of knowledge extensibility is one of the main sources of competitive advantage for innovators and creation of barriers to entry and market power at the firm level and of total factor productivity at both the firm and the system level.

A large consensus about knowledge cumulability has been encapsulated in repeated use of the well-known Newton's quote: "if I have seen further it is by standing on the shoulders [sic] of Giants". The literature has appreciated the positive effects of the extended duration of knowledge as an input in the generation of further knowledge in terms of economic growth.

The resource based theory of the firm identifies in the accumulation of knowledge the basic element of the bundle of resources that defines a firm (Penrose, 1959; Kogut and Zander, 1992). Along the same lines, the evolutionary literature has highlighted the intrinsic cumulativity of knowledge as a key factor of the long-term competitive advantage of innovators in product markets stressing the role of knowledge cumulatibity as a major source of barriers to entry and asymmetric profitability (Dosi, 1988).

The technology management literature has identified the cumulativity of knowledge as the key element that accounts for the persistence of innovativity: firms that have been able to build up a knowledge base are more likely to remain innovators in the long term, especially if the strength of their internal knowledge base is complemented by the effective access to the stock of knowledge. As Teece (2000: 37) notes: "Technology development, particularly inside a particular paradigm, proceeds cumulatively along a path defined by the paradigm. The fact that technological progress builds on what went before, and that much of it is tacit and proprietary, means that it usually has significant organization-specific dimensions. Moreover, an organization's technical capabilities are likely to be close to the previous technological accomplishments". Cefis and Orsenigo (2001) provide strong empirical evidence on the cumulability of knowledge within firms and its role in accounting for the persistence in the rates of introduction of innovations.

In this literature the emphasis on the role of the internal accumulation of knowledge is more and more complemented by appreciation of the central role of the accumulation of and the access to the stocks of quasi-public knowledge available in the system (Antonelli, 2000; Antonelli et al., 2015).

The relevant duration of patent terms -20 years in the European Union and in the United States- can be considered a reliable clue of the current consensus about the limited exhaustibility of knowledge and the extended duration of its economic value.

As a matter of fact, the limited exhaustibility of knowledge lies at the heart of its non rivalry in use, another – much better known- property. Non rivalry in use applies to public economic goods characterized by indivisibility of benefits: "A good is non-rival or indivisible when a unit of the good can be consumed by one individual without detracting, in the slightest, from the consumption opportunities still available to others from that same unit. Sunsets are non-rival or indivisible when views are unobstructed." (Coornes and Sandler, 1986: 6). The definition of non-rivalry in use has been progressively stretched and applied to a variety of impure public goods including knowledge (Stiglitz, 1999). Its application to knowledge has not appreciated an important implication: non-rivalry in use of knowledge takes place not only because of its non-excludability, but also because of its limited exhaustibility. The possibility to sharing knowledge, and yet retaining the possibility to keep using it, is possible only because of its non-exhaustibility. It seems quite obvious that the use by an agent of a standard excludable economic good characterized by standard exhaustibility excludes the possibility that a second agent can keep using it at the very same conditions. The limited exhaustibility of knowledge and its non excludability, stemming from its limited appropriability, are intertwined since the very first steps of the economics of knowledge. It is necessary to disentangle their separate effects.

The comparative analysis of standard economic goods and knowledge shows that the exhaustibility of knowledge is much lower than the exhaustibility of standard economic goods. Standard economic goods are characterized by high levels of exhaustibility. Consumer goods, such as food or personal services are fully exhausted by their consumption. Durable consumer goods have lower levels of exhaustibility: yet their duration is limited. Intermediary goods are fully exhausted by their transformation into output. Capital goods have a longer duration. Economic obsolescence is usually faster than their physical exhaustion. The introduction of superior capital goods makes existing capital goods that are not yet exhausted by physical wear and tear, obsolete.

The exhaustibility of knowledge is far more limited. Consumption of knowledge as a final good does not imply its exhaustion. The use of knowledge as an intermediary input does not entail exhaustion. The same piece of knowledge can be used repeatedly as an intermediary input without any effect on its duration. Finally, the use of knowledge as a capital good does not entail any physical wear and tear. The duration of knowledge as a capital good may be exposed to economic, rather than physical obsolescence. Yet "old" knowledge yields strong economic effects as an input for the generation of new knowledge.

The understanding of the multiple role of knowledge that acts twice as an input and once as an output unveils another limit to its exhaustibility. Knowledge in fact is an essential input in the technology production function, i.e. the production of all kind of goods (Griliches, 1979, 1984, 1986, 1992; Griliches and Pakes, 1984) as well as the output of the knowledge generation as a dedicated activity (Jaffe, 1986). The generation of knowledge as an output, moreover, is the result of the recombination of existing knowledge: knowledge enters the knowledge generation function as an indispensable input (Weitzman, 1996). Even after that existing knowledge experiences economic obsolescence as a capital good used in the production of other goods, it remains an indispensable input in the generation of new knowledge.

The analysis of the multiple role of knowledge as: i) an input in the technology production function; ii) an output of the knowledge generation function; iii) an input in the knowledge generation function, enables to grasp the radical difference in terms of exhaustibility of knowledge as a capital good with respect to standard capital goods. The economic obsolescence of standard capital goods entails their economic exhaustion. This is not the case of knowledge. Its economic obsolescence may entail its exhaustion as an effective capital good in the technology production function, but not in the knowledge generation function, where it remains an indispensable intermediary input. The limited exhaustibility of knowledge has important implications for economic analysis and policy.

The limited exhaustibility of knowledge combined with its limited appropriability is at the origin of the accumulation of a stock of quasi-public technological knowledge that keeps increasing -in size and variety- with typical non-ergodic features and can yield, with appropriate systemic conditions, dynamic increasing returns supporting the creative response of firms caught in out-of-equilibrium conditions.

The use of the stock of quasi-public knowledge is indispensable for the generation of new knowledge, and yet its access and use are rooted in the web of knowledge governance mechanisms that are localized in the economic systems of advanced countries. As a consequence, countries that have a larger and wider stock at a given point in time, provided their knowledge governance mechanisms are and remain effective, are likely to benefit of an increasing competitive advantage amplified by the powerful dynamic effects of the accumulation of the knowledge stock so that they specialize more and more in knowledge intensive products.

The effects of the limited exhaustibility of knowledge may compensate the effects of its limited appropriability. The Arrovian knowledge market failure takes place only when and if the downward shift of the intertemporal derived demand for non-exhaustible knowledge engendered by the limited appropriability of knowledge and the consequent decline of the price of innovated goods is larger than the downward shift of the intertemporal derived demand of standard capital goods engendered by their obsolescence. The analysis of the derived demand is a powerful tool that enables to identify the effects of the limited exhaustibility of knowledge compared to the standard exhaustibility of economic goods that enter a technology production function as capital (and intermediary) inputs (Antonelli, 2017a).

The formal analysis of the derived demand for technological knowledge enables to follow and yet stretch the application of the Arrovian approach from the analysis of knowledge as an output to the analysis of knowledge as an input. We can proceed with the same comparative approach confronting the outcomes of knowledge as a standard good with substantial exhaustibility to the outcomes of knowledge as a non-standard good characterized by limited exhaustibility.

The analysis of the derived demand of a capital good with an economic life that lasts more than a single unit of time requires to take into account the distribution of the yearly economic benefits distributed over the stretch of time along which the capital good remains into operation, taking into account the erosion effects of its obsolescence. When the economic life of a capital good exceeds the single unit of time it is necessary to move from the instantaneous derived demand to the intertemporal derived demand.

The intertemporal position of the derived demand of any intermediary and capital good (K) is determined by the horizontal sum of the instantaneous derived demand schedules, that is the yearly schedules of its ($P_YP'_K$) the product of the price (P_Y) of the output (Y) and marginal product in physical quantities (P'_K) taking into account the rates of obsolescence that reduce the portion of the capital good in use each year.

For the same token, the intertemporal derived demand of knowledge as an input in the technology production function is determined by the horizontal sum of the instantaneous derived demands measured at each point in time by its marginal product in value ($P_YP'_{TK}$) that is the marginal product in physical quantities of the knowledge stock (TK) as an input in the technology production function- times the price of output Y, taking into account the rates of obsolescence that reduce the portion of the capital good in use each year (Antonelli, 2017a).

The rates of obsolescence play a major role to identify the position of the intertemporal derived demand as they have a strong effect on the time distribution of the sequence of marginal products of the portions of input that remain in the production process. At each point in time the position of the intertemporal derived demand is determined by the sum of the instantaneous schedules of derived demand over the stretch of time through which the knowledge input exerts its productive effects taking into account the non-exhausted portion still effective.

The starting point is the Cobb-Douglas specification of the knowledge production function:

(1) $Y = K^{\alpha} L^{\beta} TK^{\gamma}$

where Y stands for the output, K for the capital stock, L for the labor input and TK for the knowledge stock.

In the case of standard intermediary and capital goods the economic and physical obsolescence entails the yearly reduction of their marginal product in value ($P_Y P'_K$). Assuming standard economic parameters, the ($P_Y P'_K$) of the first year is 100%, the ($P_Y P'_K$) of the second year is reduced to 80%, the ($P_Y P'_K$) of the third year is reduced to 60% and so on until the capital good is fully exhausted[1].

According to the analysis conducted above it seems possible to claim that the exhaustion of knowledge in its dual role of capital good in the technology production function and intermediary good in the knowledge generation function takes place at slow rates. Much slower than any standard economic good.

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[1] The rates of tax depreciation provide a reliable clue about the actual obsolescence of tangible capital goods. Although they exhibit a relevant variance - the heights of 30-40 % for petrochemical and digital capital goods, to 25% for machinery- they confirm that the average duration of the economic life of tangible capital goods rarely exceeds 4 years.

In the case of knowledge, the economic and physical obsolescence entails a far lower yearly reduction of its marginal product in value ($P_YP'_{TK}$). Assuming a possible parameter, the ($P_YP'_{TK}$) of the first year is 100%, the ($P_YP'_{TK}$) of the second year is reduced to 95%, the ($P_YP'_{TK}$) of the third year is reduced to 90% and so on until knowledge is actually exhausted.

Because the analysis implemented so far does not take into account the effects of the limited appropriability of knowledge, it seems clear that the position of the intertemporal derived demand of knowledge, calculated as the horizontal sum of the yearly schedules of the marginal products in value of the non-exhausted portions of knowledge, is far higher than the position of the intertemporal derived demand of any other capital good.

The intertemporal derived demand of standard capital goods, assuming that the current period is t_1 and the initial year t_0 and taking into account depreciation/obsolescence (d), is:

$$(2) \quad D = \sum_{t=t_0}^{t_1} \quad (1-d)^{t_1-t} P_Y P'_{K_t}$$

The instantaneous derived demand of knowledge (where the depreciation/obsolescence rate is equals the instantaneous derived demand of any other capital good) is:

$$(3) \quad \sum_{t=t_0}^{t_1} \quad (1-d)^{t_1-t} P_Y P'_{K_t} = \sum_{t=t_0}^{t_1} \quad (1-\delta)^{t_1-t} P_Y P'_{TK}.$$

when:

$$(4) \quad d = \delta$$

The intertemportal derived demand for knowledge is larger than the intertemporal demand for capital when the effects of the duration of capital goods and knowledge over a stretch of time that is larger than the unit are taken into account:

$$(5) \quad d > \delta$$

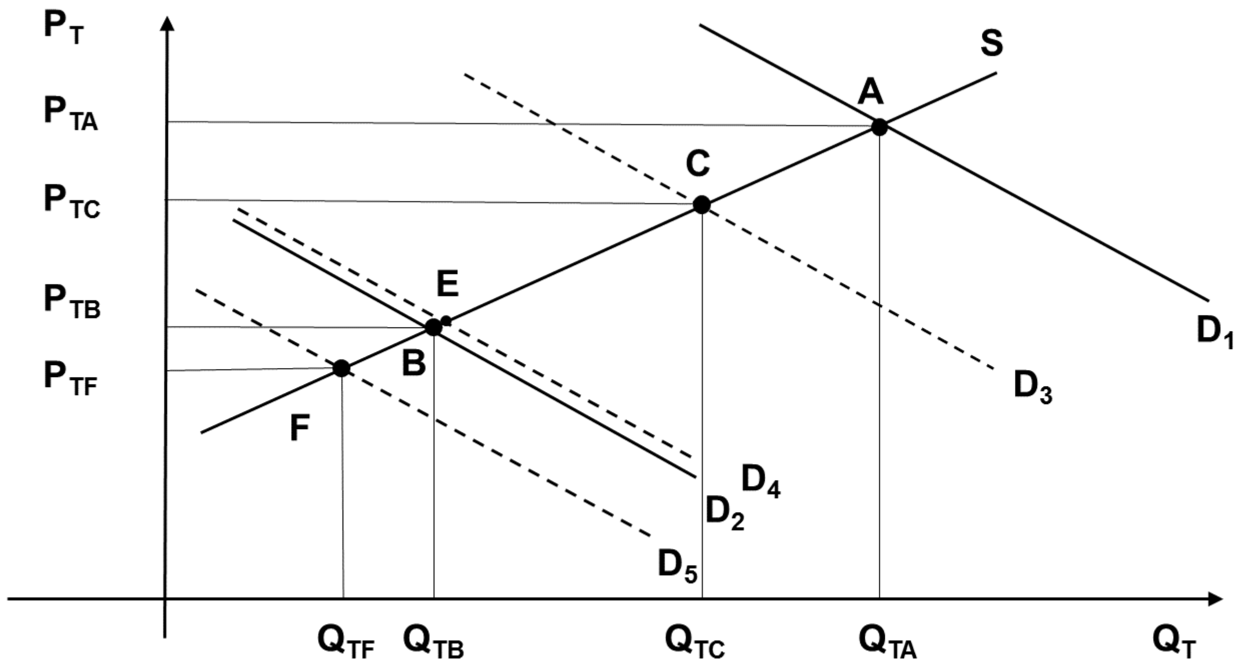
Equation (5) holds because the exhaustibility of knowledge is lower than the exhaustibility of standard capital goods and consequently larger portions of knowledge capital remain in service with respect to contemporary capital goods. As a consequence, the intertemporal derived demand for knowledge lies far above the derived demand for any standard capital good:

$$(6)\quad \sum_{t=t_0}^{t_1} (1-d)^{t_1-t} P_Y P'_{K_t} < \sum_{t=t_0}^{t_1} (1-\delta)^{t_1-t} P_Y P'_T$$

Figure 2.1 shows the implications. The higher position of the intertemporal derived demand for knowledge (D_1) stemming from its limited exhaustibility contrasts the lower position of the intertemporal derived demand for standard economic goods (D_2) stemming from their higher levels of exhaustibility that reduce the efficiency time window of a given capital good. The position of (D_2) can be regarded as the benchmark. Out-of-equilibrium conditions take place when the position of the derived demand for knowledge does not coincide with the benchmark and lies either above or below it.

Assuming a standard supply curve (S) with a positive slope, it is clear that, not only the equilibrium demand for knowledge (Q_{TA}) is larger than the equilibrium demand for any standard economic good, (Q_{TB}) but also the price of knowledge (P_{TA}) is larger than the benchmark equilibrium price of any standard capital good (P_{TB}).

FIGURE 2.1. THE DERIVED DEMAND FOR KNOWLEDGE AND STANDARD ECONOMIC GOODS WITH DIFFERENT LEVELS OF EXHAUSTIBILITY AND APPROPRIABILITY



Because of the crucial role of the limited exhaustibility of knowledge - without taking into account the effects of its limited appropriability- the incentives to allocate resources to generate knowledge are not lower but actually larger than the incentives to allocate resources to standard economic goods. The analysis of the effects of the limited exhaustibility of knowledge suggests, in fact, that markets may oversupply knowledge rather than undersupply it. The Arrovian market failure would work the other way around: too much knowledge is generated and too little standard capital goods are demanded by the system. Too much investment in knowledge takes place and too little investments take place in standard tangible goods. Because of excess duration of its economic life there is an excess-supply of knowledge.

2.5. THE KNOWLEDGE APPROPRIABILITY TRADE-OFF

The analysis of the generation and exploitation of knowledge has enabled to identify both the negative consequences of its limited appropriability and of its uncontrolled leakage that undermine the profitability and the positive effects of its un-limited extensibility that enable to apply the very same knowledge item to unlimited output items, and of its limited exhaustibility and consequent cumulability that enable to extract relevant rents. The exploitation of knowledge is consequently a highly contextual process whose actual outcome is strictly contingent upon the institutional and economic conditions in which it takes place.

The contradiction between the role of knowledge as a necessary input in the generation of new knowledge and its exploitation conditions is at the origin of the intrinsic weakness of the knowledge growth regime. The limited appropriability of knowledge combined with its limited exhaustibility enhances the rates of generation of knowledge and empowers the dynamic increasing returns at the system level stemming from the accumulation of the flows of current knowledge in a stock of quasi-public knowledge. The larger and wider is the stock and the lower is its cost.

The exclusivity of IPR endangers the viability of the knowledge growth regime. At the same time, it is clear that the limited appropriability of knowledge and the risks of uncontrolled knowledge leakage limits its exploitation and hence its profitability with the well-known consequences of market failure. The solution of the appropriability trade-off is indispensable. The introduction of IPR with limited exclusivity seems to provide a suitable solution to the well known appropriability trade-off.

The formal analysis of interplay between positive and negative knowledge externalities builds upon the knowledge generation function with its cost equation. The net effects of knowledge externalities can be calculated as the algebraic sum of the gross positive effects of knowledge spillovers on the costs of knowledge as an input and the negative effects of the limited appropriability on the price of knowledge as an input.

Knowledge externalities are actually positive only when the positive effects in terms of the reduction of the costs are larger than the negative effects in terms of the reduction of the revenue. These are net positive pecuniary knowledge externalities.

In a Cobb-Douglas specification of the knowledge generation function, standard substitution –albeit limited by substantial complementarity- between the two basic inputs affect total and average costs with non-linear effects. On the output side, instead, the effects on the price, have, linear effects on the revenue. It is consequently possible to identify an optimum level of knowledge appropriability (Antonelli, 2013, 2015a).

The knowledge generation function, in the standard c.r.s. Cobb-Douglas specification, and the knowledge cost equation are:

(1) $Y = R\&D^{d}\, TK_{(t-1)}^{\;1-d}$
(2) $TC_{Y} = zR\&D + vTK_{(t-1)}$

Where Y stands for the flow of knowledge output, R&D for internal research and learning activities, TK, for the stock of quasi-public knowledge (at time t-1) and d measures the output elasticity of R&D. Both R&D and TK have a cost. The cost z measures the costs of research activities; the cost v measures the cost of using and accessing the stock of quasi-public knowledge.

The stock of all the existing knowledge generated until that time, is a complementary, indispensable input into the generation of new knowledge. The costs of accessing and using the stock of quasi-public knowledge v are a function of the its size and variety. For given levels of the size and variety of the stock, the quality of knowledge governance mechanisms at work in the system: when it is high the costs of the stock of quasi-public knowledge (v) is low.

The levels of the costs of accessing and using the stock of quasi-public knowledge affect the knowledge generation function. In the latter, in fact, both R&D and TK are fundamental and indispensable inputs. No knowledge can be generated without the access to the stock of quasi-public knowledge and dedicated research activities. The reduction of v, the costs of the stock of quasi-public knowledge, triggers a substitution process that has a limit. In the standard Cobb-Douglas production function, factor substitution is bounded as it is constrained by the well-known borders.

The recombinant character of the knowledge generation process stresses the limits to the substitution process: either factor cannot fall below threshold levels. A –large- minimum amount of both the access to the stock of knowledge and internal research activities is necessary in order to generate new technological knowledge[2]. Hence the costs of the knowledge output (TC_Y) indeed decline if the costs of the cost of accessing and using the stock of knowledge, v, as an input, decline. Yet, because of the bounded substitution that takes place within the knowledge generation function, the reduction is less than proportionate.

As in the standard Cobb-Douglas we assume that the two inputs are complements with a certain -limited- degree of substitutability. In other words, the generation of knowledge requires a minimum amount of both R&D and $TK_{(t-1)}$. Even if appropriability is small as well as royalties and v is low, knowledge generation cannot rely exclusively on R&D. A minimum amount of $TK_{(t-1)}$ must be used in any case. Let us call this minimum amount $TK_{(t-1)\ min}$. Let us call $R\&D_{max}$ the corresponding level of research and learning activities:

(3) $R\&D_{max} = xTK_{(t-1)}{}^{(\alpha-1)}{}_{min}$. Where $x>1$

According to eq. 2, total costs are the sum of the cost component related to R&D and the cost component related to $TK_{(t-1)}$. Within the given substitutability range, if the access cost to the stock of knowledge v decreases, the production of knowledge Y relies less on $TK_{(t-1)}$ and more on R&D. When v increases beyond a certain value (that we denote v*), however, $TK_{(t-1)}$ cannot further decrease. This implies that for $v > v^*$ (namely, out of the substitutability range) the component of cost related to R&D remains constant, while the component of costs related to $TK_{(t-1)}$ decreases linearly with v:

(4) $TC_Y = z\ R\&D_{min} + v\ TK_{(t-1)}{}^{*}{}_{max}$

We thus have that the cost curve, in its two linear components, with respect to v, can be approximated by a homothetic function that exhibits a non-linear relationship with an upward concavity.

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[2] The empirical evidence of Antonelli and Colombelli (2015) confirms the hypothesis that the knowledge generation function exhibits the typical traits of an o-ring technology.

Following Arrow, (1962a) we assume that the price of knowledge (P_Y) is a positive and linear function of the levels of the de facto appropriability of knowledge (DFA) within the system:

(5) $P_Y = l(DFA)$

Where 0>DFA<1. When DFA=0 technological knowledge cannot be appropriated. When DFA=1 it is fully appropriated: 100% of the revenues stemming from the proprietary knowledge is actually appropriated by the "inventor".

The lower are the levels of DFA and the lower the price of the good Y. We can assume that the relationship is linear and positive:

(6) $l' > 0$ and $l'' = 0$

The value of the output of the knowledge generation function – i.e. its revenue (R_Y) is directly determined by the price of knowledge as an output. Hence the lower the levels of the DFA and the lower the revenue of the producer of knowledge that uses knowledge as a necessary input.

The apparatus built so far enables to compare the positive and negative effects of the appropriability of knowledge in a single framework. Pecuniary knowledge externalities enable to compare the negative effects of knowledge appropriability in terms of reduction of the price of the knowledge as an output, with the its positive effects, in terms of reduction of the cost of knowledge as an input.

The analysis of knowledge as both an input and an output shows that both the price -and hence the revenue- and the cost of Y are influenced by the levels of knowledge appropriability. The apparatus makes it possible to identify the optimum level of knowledge appropriability. Because of the differences in slopes of the cost and revenue functions, the relationship between positive and negative effects changes according to the levels of appropriability: there is clearly an optimum level of appropriability. Before and after it the positive net effects of pecuniary knowledge externalities are lower.

INSERT FIGURE 2.2 ABOUT HERE

Figure 2.2 exhibits the framework elaborated so far as it makes explicit the relationship between the price and the cost of knowledge and the levels of knowledge appropriability. The upper section exhibits the relevant cost and revenue curves according to the levels of knowledge non-appropriability (1-DFA): the outcome is clearly positive. The limited appropriability of knowledge triggers a reduction of costs that is larger than the reduction of prices. The optimum level of the limits to appropriability (1-DFA)* is easily identified when:

(7) $DFA^* = dR_Y/dDFA - dTC_{KN}/dDFA = 0$

The lower part of Figure 2.2 exhibits the non-linear consequences of the net positive effects of pecuniary knowledge externalities. The optimum level of non appropriability (1-DFA) -defined in the upper part of Figure 2.1- by the maximum distance between the effects of appropriability on the revenue (R_Y) and its effects on the costs (TC_Y), in terms of the effects on total factor productivity. Net pecuniary knowledge externalities, in fact, trigger the increase of total factor productivity (Antonelli, 2017a).

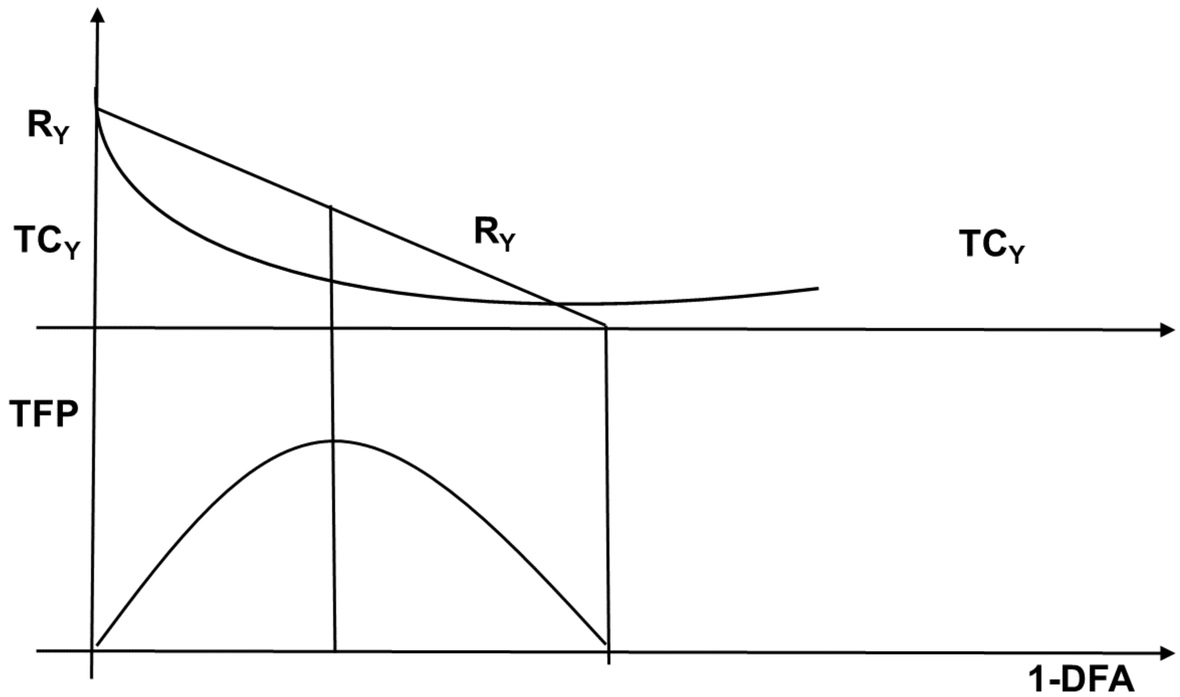
Figure 2.2 makes clear that, according to the differentiated effects on the levels of prices and costs, respectively, knowledge is indeed quite a special good. Full appropriability is not necessarily good for an economic system, neither a zero level of appropriability is good for the system. Actually, specific intermediary levels of knowledge leakage and dissemination produce net positive effects at the system levels. The analysis of knowledge as an input and an output enables to identify the level of the price of knowledge that maximizes the net pecuniary externalities and yet includes profits for knowledge producers.

This section has demonstrated that the perfect and full appropriability of knowledge is suboptimal, as much as the zero appropriability. The partial appropriability of knowledge is clearly superior from a welfare point of view.

Note that the actual conditions of use of knowledge spillovers have relevant effects on the optimum amount of non-appropriability of knowledge. Figure 2.2 makes clear that the slope of the revenue function depends upon the extent to which the limited appropriability of knowledge affects the revenue and the profits of “inventors”.

The analysis of the joint effects of the limited appropriability and exhaustibility of knowledge and its dual role, as an output and an input of the knowledge generation function shows that both the perfect and full appropriability of knowledge and the zero appropriability are suboptimal. There is a partial level of appropriability that yields an optimal mix of incentives to its generation.

FIGURE 2.2. POSITIVE AND NEGATIVE EFFECTS OF THE LIMITED APPROPRIABILITY OF KNOWLEDGE



2.6 INTERINDUSTRIAL VS INTRAINDUSTRIAL SPILLOVER

The analysis of the knowledge base of general purpose technologies that apply to a wide range of product markets sheds new light on the appropriability trade-off (Bresnahan and Trajtenberg, 1995; Lipsey et al., 2005). This section explores the effects of the limited appropriability of knowledge on the technology production function according to the use of spillovers. The reduction of the revenue triggered by imitation is large when proprietary knowledge spills to competitors active in the same product market that use it as an input –ready to be used as such- in their technology production with evident and strong negative effects on the price of the innovated products, the revenue of "inventors" and their profitability. The reduction instead is small when proprietary knowledge spills to firms active in other product markets that use it as an input in the recombinant generation of knowledge and innovation in other product markets: this use of the proprietary knowledge has limited effects on the price of innovated products, the revenue of inventors and their profitability.

The distinction between intraindustrial and interindustrial spillovers enables to operationalize the fine tuning of intellectual property rights in terms of differentiated levels of exclusivity. Interindustrial spillovers yield far larger net pecuniary knowledge externalities than intraindustrial spillovers.

INSERT FIGURE 2.3 ABOUT HERE

Figure 2.3 presents an analysis of the twin effects of knowledge spillovers based upon the Arrovian insight that explores the characteristics of knowledge as an economic good. It compares the twin effects of knowledge spillovers, in terms of positive and negative pecuniary externalities, assuming as a benchmark the case of knowledge as a standard economic good and confronting to it the effects of the actual properties of knowledge.

In Figure 2.3, the demand curves D_1 and D_2 represent the derived demand for knowledge that stems from a technology production function where knowledge enters as an input, next to standard capital and labor, in the production of all the other goods (Antonelli, 2017a). The position of the derived demand D_1 assumes that knowledge is a standard economic good with full appropriability. The position of the derived demand D_2 reflects the negative effects of the limited appropriability of knowledge on the price of the goods produced by the technology production function.

In Figure 2.3, the supply curves S_1 and S_2 stem from the marginal cost of knowledge. The supply curve S_1 represents the case of knowledge as a standard economic good and the supply curve S_2 represents the actual case of knowledge with its idiosyncratic and specific properties. The shift reflects the positive effects of knowledge spillovers on the cost of the stock of knowledge.

Figure 2.3 provides a simple welfare analysis of the combined effects of knowledge appropriability in terms of positive externalities stemming from the spillover and the consequent reduction of the cost of the stock of knowledge, and negative externalities stemming from the fall of the price of products that embody proprietary knowledge as an input.

Figure 2.3 identifies:
i) the surface area of the quadrangle AZIC as the size of the negative externalities stemming from the limited appropriability in terms of the downward shift of the derived demand of knowledge with the consequent loss of consumer surplus;

ii) the surface area of the quadrangle BEDC as the size of the positive effects of the limited appropriability of knowledge in terms of spillover with the consequent reduction of the cost of knowledge.

The ratio of the size of the surfaces AZIC/BEDC measures the appropriability trade-off. When AZIC/BEDC>1, the Arrovian market failure applies and appropriability conditions should be reinforced. When, instead AZIC/BEDC<1, the limited appropriability of knowledge yields superior welfare effects.

The distinction between intraindustrial and interindustrial uses of knowledge spillovers is most relevant in this context. Intraindustrial knowledge spillovers allow the use of the knowledge, spilling from the introduction of new knowledge, within the same product market by competitors. Intraindustrial spillovers consist of the use of knowledge by firms active in other product markets. Let us now assume that in Figure 2.3 the derived demand D_2 represents the situation of interindustrial spillovers and the derived demand D_3 represents the case of intraindustrial spillovers.

When intraindustrial spillovers apply, the leftward shift of the derived demand for knowledge D_3 is larger, as their use by competitors has direct and strong -negative- effects on the price of the products. When interindustrial spillovers apply, the shift of the derived demand for knowledge D_2 is smaller as the users are active in other product markets. We assume that the same shift of the supply curve S_2 applies in both cases as absorption costs are the same for both inter and intra industrial spillovers.

Let us now implement the welfare analysis, again with the support of Figure 2.3, to compare the cases of interindustrial and intraindustrial spillovers. When intraindustrial spillovers apply, the leftward shift of the derived demand for knowledge D_3 is far larger than D_2 when interindustrial spillovers apply. Hence it seems clear that:

(1) AZIC/BEDC<1; aZic/BEDC <1

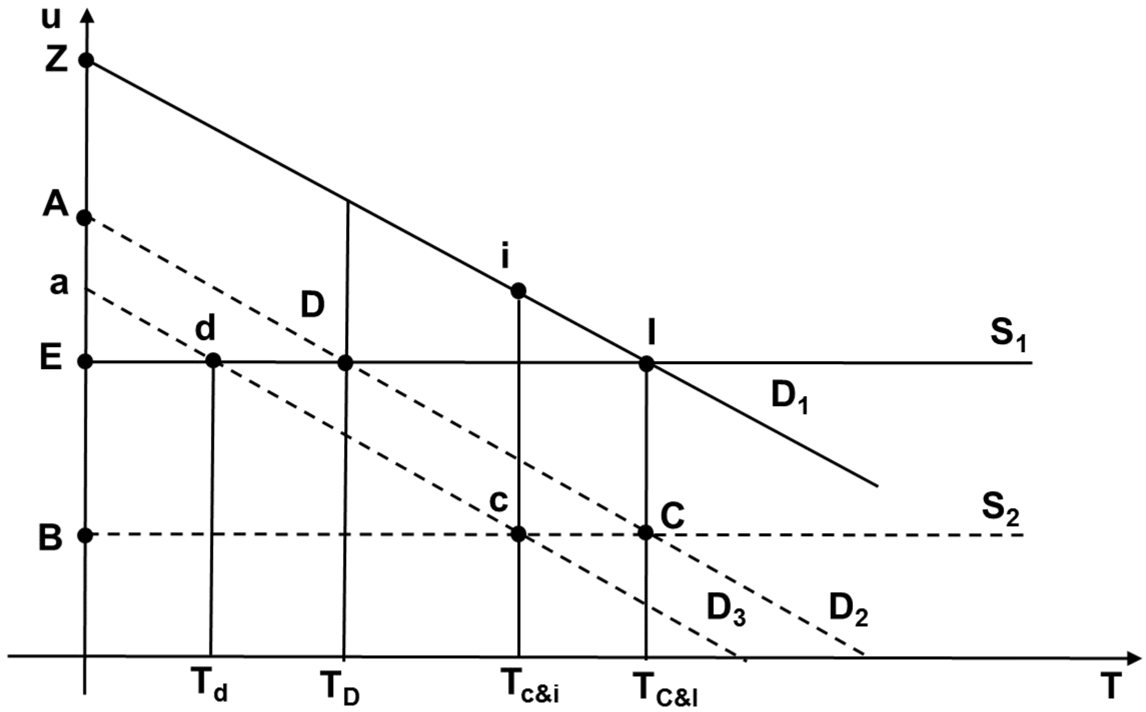
The optimal levels of appropriability are lower with interindustrial than intraindustrial spillovers. The identification of the differentiated effects of knowledge spillovers whether interindustrial or intraindustrial has major implications for the design of a differentiated property right regime.

The distinction between imitation and knowledge externalities is relevant to assess the appropriability trade-off. Imitation externalities stemming from intra-industrial spillovers favor the entry of new competitors that benefit of knowledge ready-to-use with negative effects that are far stronger than the positive ones. Knowledge externalities stemming from inter-industrial spillovers take place when knowledge spilling from one party can be used as an input in the knowledge generation function with positive effects that are far larger than the negative ones.

The appreciation of the joint effects of the limited exhaustibility of knowledge and of the knowledge appropriability trade-off calls for the design of a new knowledge policy framework based upon the differentiation of both public subsidies with respect to their actual additionality and IPR with respect to terms and levels of exclusivity (See Chapter 6).

The exclusivity of patents should vary according to the uses of knowledge whether it is intraindustrial and hence an input –ready-to-be-used into the technology production function of competitors in the same product market, or interindustrial and hence an input into the knowledge generation function of firms active in other product markets.

FIGURE 2.3 A WELFARE ANALYSIS OF THE POSITIVE AND NEGATIVE EXTERNALITIES OF KNOWLEDGE APPROPRIABILITY



2.7 KNOWLEDGE AND FINANCE

Both the generation and the exploitation of knowledge, as an economic good, are characterized by high levels of risks that reach almost the threshold of radical uncertainty. The Schumpeterian legacy provides the basic tools to explore the implications of the limitations of knowledge as an economic good with respect to the provision of finance to fund its generation and use.

The high levels of risks that characterize both the generation -the outcome of research activities is characterized by levels of risks close to uncertainty- and the exploitation of knowledge -the actual appropriability of the knowledge generated is at risk- expose research activities to substantial credit rationing and excess costs of financial resources.

In his *Theory of economic development* Schumpeter stresses the central role of the “innovative banker” for the provision of appropriate financial resources to fund the introduction of innovations by entrepreneurs. The innovative banker is the indispensable interface between financial resources and innovation. The banker is innovative when he is able to spot new opportunities and select, among the myriads of the business proposals that are daily submitted, those which have higher chances to get through the system and yield successful innovations. With a given quantity of financial resources the innovative banker should be able to reduce the flow of funds towards traditional activities and switch them towards the new innovative firms. Actually, the innovative banker should be able to identify the obsolete incumbents that are going to be forced to exit by the creative destruction that follows the entry of successful innovators.

The historic evidence has shown that debt finance for innovation suffers a major limit. Banks suffer an intrinsic asymmetry: they are fully exposed to the failures of risky undertakings but cannot participate to the extraordinary profits of the rare undertakings that actually survive and introduce successful innovations.

Debt finance exerts a perverse effect on the rate of introduction of innovations. In order to compensate for the capital losses stemming from non performing loans bankers in fact need to charge high interest rates. High interest rates charged to new ventures are themselves a cause of failure that reduces the chances of successful introduction of innovations. Only radical innovations with high levels of profitability can survive the financial burden.

To cope with the limitations of intrinsic asymmetry, in Continental Europe the “innovative banker” implemented the mixed banking system that combines deposit banking with investment banking and provides long term loans to new industrial ventures and participate into their equity. Mixed banking could support the successful introduction of innovations via the participation into their equity: the capital gains of the winners could balance the losses of the loosers. At the same time, however, the increasing share of long term investment had negative effects on the portfolio of banks, reduced their liquidity and exposed them to dramatic failures that lead to the collapse of a large part of the European financial system especially in Austria, Germany and Italy in the third decade of the 20^{th} century

Schumpeter not only realized the limits of the "innovative banker" but identified the advantages of the new model emerging in the US economy at the beginning of the XX century. The analysis of the corporation as the institutional alternative to the 'innovative banker' has been laid down in *Capitalism socialism and democracy*. Here Schumpeter identifies the large corporation as the driving institution for the introduction of innovations. Schumpeter is very clear in stressing the role within corporations of the internal financial markets where the resources extracted by extra-profits can match the competences of skilled managers and the vision of potential entrepreneurs. Moreover, the corporation can act as an intermediary between the credit markets and the provision of funds for new innovative undertakings. The corporation can borrow, acquire financial resources at low costs for the low risks associated with its status of large incumbent with barriers to entry, stir and select new undertakings, fund directly the new ventures and participate in the provision of selective equity.

The intrinsic asymmetry between the provision of credit and equity to new ventures is solved by means of the internal financial markets that favor the matching between resources, technological knowledge and market competence. Schumpeter praises the large corporation as the institutional device that makes it possible to increase both the incentives and the efficiency of the innovation process. The internal markets of the Schumpeterian corporation substitute external financial markets in the key role of the effective provision and correct allocation of funds combining financial resources and entrepreneurial vision within competent hierarchies (Chandler, 1962 and 1977).

According to Stiglitz (Stiglitz and Weiss, 1981) equity finance can participate into the bottom tail of the highly skewed distribution of positive returns stemming from the generation of new knowledge and the introduction of new technologies. This has important consequences in terms of reduction of both the risks of credit rationing and the costs of financial resources for research activities. Lenders in fact need to charge high interest rates in order to compensate for the risks of failure and to sort out a large portion of the new research activities to avoid as many 'lemons' as possible. Equity investors instead find an equilibrium rate of return at much lower levels because they can participate into the huge profits of a small fraction of the new ventures. The fraction of lemons that equity can support is much larger than that of debt, hence, as a consequence, financial equity can provide a much larger amount of funding for research activities.

With a second line of analysis Stiglitz has questioned the apparent superiority of equity finance over debt finance with the distinction between hierarchies and polyarchies as alternative mechanisms to manage different types of risks (Sah and Stiglitz, 1986 and 1988). Hierarchical decision-making is better able to avoid the funding of bad projects. Yet the ability of hierarchies is limited by the scope of their competence: their decision-making tends to favor minor, incremental changes and exclude radical innovations with typical Type 2 errors. Polyarchic decision making, on the opposite, experiences higher risks to including bad projects, e.g. Type 1 errors, but yields higher chances of inclusion of outstanding projects. According to Stiglitz, hierarchical decision-making fits better in economic environments characterized by low levels of entropy and radical uncertainty. Conversely, polyarchic decision-making applies better in times when the levels of radical uncertainty are higher.

The distinction between Type 1 and Type 2 errors proves to be very useful to assess the working of alternative mechanisms and forms of decision making in the selection and implementation of new technological knowledge. The argument elaborated by Stiglitz can be used upside-down so as to investigate what type of decision-making yields higher results in terms of the generation of new technological knowledge and the eventual introduction of innovations.

Hierarchies are more likely to incur Type 2 errors that arise when good innovative projects are excluded. Hence hierarchical decision-making has higher chances to favor incremental innovations and to exclude innovative undertakings that are disruptive and may trigger problems in terms of discontinuities both with respect to the existing knowledge base and sunk costs. Polyarchic decision-making, based upon a variety of competences, selected on a professional basis according to their expertise and less exposed to vested interests, on the opposite, favors the inclusion of a wider range of projects. As a consequence, polyarchies tend to include also bad projects. But the likelihood that outstanding projects are retained is much higher. The occurrence of radical innovations seems higher with polyarchic architectures.

The combination and implementation of the two tools provided by Stiglitz enables the comparative assessment of the alternative institutional mechanisms designed to handle the relationship between finance and innovation and identified by Schumpeter: banks and corporations. The analysis of their limitations, with the tools provided by Stiglitz, enables to identify the emerging venture capitalism as a third distinctive mechanism.

Banks can be considered much closer to polyarchic decision-making. They can rely upon a variety of expertise and competence that are hired on a professional base. Their competence is much less constrained by a given scope of expertise and the effects of irreversibilities and vested interests are much lower. As such banks seem better able to avoid Type 2 errors. Banks have a clear advantage in the screening process, but their action is limited by clear disadvantages in the participation to the profits stemming from new innovative undertakings. Banks are exposed to the intrinsic asymmetry between debt and equity in the provision of funds to innovative undertakings. This is true especially when radical innovations occur. The higher the discontinuity brought about by radical innovations and the larger the risks of failure of new companies. Banks bear the risks of the failure of firms that had access to their financial support but cannot share the benefits of radical breakthroughs. As Schumpeter himself realized, this model, although practiced with much success in Germany in the last decades of the XIX century, suffered from the severe limitations brought about by this basic asymmetry.

The Schumpeterian corporation confirms that equity-finance is more effective than debt-finance for channeling resources towards innovative undertakings, but with a substantial bias characterized by continuity with the existing knowledge base. The model of finance for innovation based upon the corporation ranks higher than the model based upon banks as far as equity-finance is more efficient than debt-based finance with respect to risk sharing, but has its own limitations arising from the reduction of the centers able to handle the decision-making and the ensuing reduction of the scope of competence that filters new undertakings.

In the second part of the XX century a few corporations concentrated worldwide a large part of the provision of finance for innovation. The limited span of competence of a small and decreasing number of incumbents made more and more difficult to identify and implement new radical technologies: a case of locked-in-competence could be observed. The corporation has been able for a long part of the XX century to fulfill the pivotal role of intermediary between finance and innovations, but with a strong bias in favor of incremental technological change. The screening capabilities of corporations fail to appreciate radical novelties.
The new financial markets are becoming a key component of an innovation driven novel institutional setting and subsystem termed "Venture Capitalism" which is key for a new model of 'knowledge-based' growth potentially relevant not only for ICT but also (with adaptations) for biotechnologies and new technologies at large.

Venture capitalism is a major institutional innovation based upon the identification of economies of scope in the transactions of technological knowledge bundled with managerial competence, reputation, screening procedures and equity. It has paved the way to the emergence of new surrogate markets for knowledge, i.e. financial markets specialized in the trade of knowledge intensive property rights with important benefits in terms of economics of size in portfolio management and hence profitability of investments in high-tech startups. The emergence of venture capitalism has important effects in national system of innovation of advanced countries, and it is a powerful mechanism for the production, dissemination and integration of knowledge in advanced capitalistic economies, and thereby a main driver of a 'knowledge-based' growth.

A mechanism based upon a screening procedure performed by competent polyarchies and the equity-based provision of finance to new undertakings would clearly combine the best aspects of each model. Venture capitalism seems more and more likely to emerge as the third major institutional set-up able to manage the complex interplay between finance and innovation when radical changes take place. As a matter of fact, venture capitalism combines the advantages of distributed processing typical of polyarchies with the advantages of equity-based finance over debt-based finance. Venture capitalism in fact makes it possible to combine the more effective identification of radical innovations with the more effective sharing of risks associated to the provision of funds.

The bank-based provision of funds to innovation suffers the limits of debt-based finance but ranks higher in terms of distributed processing. The advantages of distributed processing are larger, the larger is the number of banks, and the larger is the number of independent agents that participate into the screening process. The corporation model is less able to avoid Type 2 errors but enjoys the advantages of the equity-based provision of finance to innovation. The corporation model suffers especially from the grip of the past that sunk-costs and the irreversibility of tangible and intangible capital exerts upon the appreciation of new disruptive technologies. It is also clear that the smaller is the number of corporations that control the funding of innovative undertaking and the higher the risks of Type 2 errors at the system level. Venture capitalism seems able to combine the advantages of the corporation model in terms of equity-based provision of funds for innovation, with the distributed processing typical of the banking system.

Venture capital companies perform the crucial selective provision of: i) the necessary financial resources with the direct participation into the equity of new firms; and ii) management able to support scientific entrepreneurs in the engineering process that leads to the production of prototypes and their marketing test. Venture capital companies rely on qualified polyarchies to identify the promising ventures and are able to minimize both errors of exclusion and inclusion. Market trials enable to test the transformation of scientific knowledge into technological knowledge and its actual scope of application to the downstream economic activities run by corporations. Successful start-ups enter eventually the financial markets. The funders can cash the large capital gains that compensate for the losses stemming from the large share of failures. Capital gains are especially large when corporations acquire by means of take-overs the new high-tech public companies and integrate them into their production process. The acquisition of the new public companies complements if not substitutes the internal performance of R&D activities. Financial investments provide the demand for the output of the new knowledge industry.

The emergence of the new, dedicated financial markets specialized in the public transactions of the knowledge intensive property rights of new science-based start-up companies, is the necessary complementary institutional and organizational innovation that makes venture capitalism possible.

2.8 KNOWLEDGE AND TOTAL FACTOR PRODUCTIVITY

The special characteristics of knowledge in terms of limited appropriability and exhaustibility are the basic determinant of pecuniary knowledge externalities that account for the likelihood of the creative response of firms caught in out-of-equilibrium conditions, hence are indispensable for the introduction of innovations and the increase of total factor productivity. The actual output levels are larger than the expected equilibrium ones because knowledge, an essential input into the creative response, can be generated and used, in qualified institutional conditions, at costs that are below its equilibrium levels.

Following Solow (1957), we know that the level of total factor productivity is measured by the ratio between the real historic levels of output Y, and the theoretical one Y^*:

(1) $A = Y/Y^*$

In the new growth theory, knowledge is assumed to be able to trigger total factor productivity automatically. Knowledge output splits in two parts: i) an appropriable output that contributes standard production processes with constant returns to scale at the firm level, and ii) an appropriable output that spills in the atmosphere and contributes to increasing the general levels of total factor productivity. Knowledge externalities are assumed to be compatible with general equilibrium conditions as they cannot be appropriated by individual agents and apply at the system level. Spillovers stemming from the limited appropriability of knowledge are freely and symmetrically available to all the agents in the system.

In our approach, the limited appropriability and exhaustibility of knowledge may have positive effects in terms of the increase of total factor productivity only if firms are willing to undertake the risky and expensive activity that is necessary to try and generate new technological knowledge as a part of their creative reaction to out-of-equilibrium conditions. Such positive effects do take place only if the systemic conditions to accessing and using the stock of quasi-public knowledge support the creative response of firms. The actual cost of accessing and using the quasi-public stock of knowledge, as determined at the system level by the quality of knowledge governance mechanisms, as well as by its size and composition, together with the out-of-equilibrium conditions that urge firms to try and elaborate a creative response are the contingent and highly idiosyncratic conditions that account for total factor productivity growth.

Total factor productivity levels depend upon the cost of accessing and using the stock of knowledge: A > 1 when knowledge costs are below equilibrium.

After Griliches (1979), in fact, the stock of technological knowledge (TK) enters directly, as an indispensable input, next to standard -fixed- capital (K) and labor (L), a standard Cobb-Douglas production function of all the other goods with constant returns to scale. The theoretical level of Y is calculated as the result of the equilibrium use of production factors:

(2) $Y^* = K^{\alpha} L^{\beta} TK^{\gamma}$

where K, L and TK are the productive factors and α, β and γ their respective output elasticity. The marginal rates of technical substitution are:

$$\frac{\frac{\partial Y}{\partial L}}{\frac{\partial Y}{\partial K}} = \frac{\beta \cdot K^{\alpha} L^{\beta-1} TK^{\gamma}}{\alpha \cdot K^{\alpha-1} L^{\beta} TK^{\gamma}} = (\beta/\alpha)(K/L)$$

$$(3) \qquad \frac{\frac{\partial Y}{\partial L}}{\frac{\partial Y}{\partial TK}} = \frac{\beta \cdot K^{\alpha} L^{\beta-1} TK^{\gamma}}{\gamma \cdot K^{\alpha} L^{\beta} TK^{\gamma-1}} \ (\beta/\gamma)(TK/L)$$

$$\frac{\frac{\partial Y}{\partial TK}}{\frac{\partial Y}{\partial K}} = \frac{\gamma \cdot K^{\alpha} L^{\beta} TK^{\gamma-1}}{\alpha \cdot K^{\alpha-1} L^{\beta} TK^{\gamma}} = (\gamma/\alpha)(K/TK)$$

Denoting with r, w and s the unit price of the three indispensable production factors in the production of Y, the cost equation is

(4) $C = rK + wL + sTK$

Profits can be defined as:

(5) $\pi(Y) = pY(K, L, TK) - rK - wL - sTK$

where p is the price of the output Y.

The first order conditions can be obtained by deriving (5) with respect to factors K, L and TK, and putting equal to zero. This can be expressed as follows:

$$(6) \qquad \begin{aligned} \frac{\partial \pi}{\partial K} &= p \cdot \alpha \cdot K^{\alpha-1} L^{\beta} TK^{\gamma} - r = 0 \\ \frac{\partial \pi}{\partial L} &= p \cdot \beta \cdot K^{\alpha} L^{\beta-1} TK^{\gamma} - w = 0 \\ \frac{\partial \pi}{\partial TK} &= p \cdot \gamma \cdot K^{\alpha} L^{\beta} TK^{\gamma-1} - s = 0. \end{aligned}$$

From equation (6), the equilibrium conditions are:

$$(7) \qquad \begin{aligned} w/r &= (\beta/\alpha)(K/L) \\ w/s &= (\beta/\gamma)(TK/L) \\ s/r &= (\gamma/\alpha)(K/TK). \end{aligned}$$

Firms select the equilibrium mix of inputs such that the relative unit costs are equal to the marginal rate of technical substitution. Corresponding to these three conditions, the profit maximizing firm will identify TK^*, K^* and L^*, i.e. the equilibrium levels of the production factors. In such equilibrium conditions the theoretical (Y^*) and historic (Y) levels of output would necessarily coincide.

Knowledge, however, is not a standard economic good. Because of its limited exhaustibility, and hence cumulability and extensibility, its actual generation costs (s) can be lower that its theoretical costs (s^*):

(8) $s < s^*$

The access and the use of the stock of knowledge are not free. Knowledge externalities are pecuniary rather than technical. The use of knowledge as an input is possible only at a cost. Hence knowledge spillovers yield pecuniary knowledge externalities rather than pure externalities. The introduction of the notion of pecuniary knowledge externalities applies directly to the knowledge generation function and indirectly to the technology production function.

The cost of accessing and using the stock of technological knowledge may be lower than equilibrium when not only its size and variety are large but also when the quality of knowledge governance mechanisms is high. As a consequence, when firms try and cope with the out-of-equilibrium conditions of product and factor markets, and “discover” that the actual cost of knowledge is below equilibrium levels, the actual amount of technological knowledge (TK) that enters the technology production function can be larger than in equilibrium conditions. Output levels are consequently larger as reflected by the levels of total factor productivity. The amount of the residual –the difference between Y and Y*- and the actual levels of total factor productivity (Y/Y^*) depends on the extent of the gap between s and s*.

The analysis of the knowledge generation function is indispensable to grasp the determinants of the gap between s and s*.

In the knowledge generation function the knowledge flow (KN) is the output of the recombination of the existing knowledge. The knowledge generation function has two basic and indispensable inputs: the standard research and development activities (R&D) and the stock of the quasi-public knowledge. The stock of quasi-public knowledge is the sum of the flows of knowledge output (Σ KN) accumulated until that time (TK_{t-1}) and rooted in the interaction and coordination mechanisms of the knowledge governance at work in the system where firms are based. The knowledge generation function and its cost equation can be formalized as it follows:

(9) $KN = (R\&D, TK_{t-1})$
(10) $KNC = cwR\&D + zTK_{(t-1)}$

For a given budget available for the generation of new knowledge (KNC) the amount of knowledge produced at each point in time (KN) depends upon the cost of creative labor (cw) that performs R&D activities and the costs of accessing and using the stock of quasi-public knowledge (z). The unit cost of accessing and using the indispensable stock of quasi-public knowledge z depends upon the size and variety of the stock itself and the quality of the knowledge governance mechanisms in place within the system.

The quality of knowledge governance mechanisms i.e. "the array of institutional settings that combine and integrate market transactions, personal interactions and communication, ex-ante and ex-post coordination both among firms in the economic system and between them and the academic system created by the State" and makes possible the use of the stock of quasi-public knowledge, plays a central role in this context (Ostrom, 2010; Antonelli 2015a: 232).

Knowledge externalities exert their pecuniary effects twice because they consist in: i) the reduced cost (s) of the stock of knowledge (TK) that enters as an input the technology production function (see eq.1) of the goods, ii) and in the reduced cost (z) to accessing and using the stock of knowledge (TK_{t-1}) that is necessary to produce the flows of new knowledge (KN) in the knowledge generation function (see eq.9) (Crépon et al. 1998; Antonelli, 2018c).

At the system level total factor productivity is large(r) when the generation of technological knowledge takes place within economic systems that have larger and wider stocks of knowledge and high(er) levels of knowledge governance such that the costs of access and using –again- knowledge (z) are low(er) and consequently the cost of knowledge as an input into in the technology production function (s) is also low(er).

The dynamics of knowledge accumulation and total factor productivity growth depends upon the evolution of the size and variety of the stock of knowledge as well as upon the quality of the knowledge governance conditions that may improve and foster or decline and undermine the access and use conditions of the quasi-public stock of knowledge. The difference between actual and theoretical knowledge costs is influenced by the costs of access and use of the spillovers (z).

If accounting procedures were able to appreciate properly the effects of the capitalization of knowledge, both as an input and an output, and the market price of knowledge were in equilibrium, the organization of the generation of knowledge whether it takes place vertically integrated within innovative firms, or in specialized firms within the knowledge industry, would not influence the economic understanding of the relationship between knowledge as a special economic good and total factor productivity. The capitalization of knowledge as an asset as in the case of a patent or in the stock market value as in the case of a start-up or any knowledge intensive company acquired by means of take-overs and generally merger and acquisition at the current accounting system, however, is registered as production of wealth and not revenue. In such conditions the shift from a generation of knowledge vertically integrated to a generation of knowledge specialized in independent knowledge firms and traded in the knowledge markets has strong effects in terms of total factor productivity and accountability.

When the generation of technological knowledge becomes the output of specialized upstream firms within the knowledge industry the difference between s and s* is determined by the user-producer relations. When downstream knowledge users are “supplier-dominated”, upstream knowledge producers are able to retain a large share of the difference between the actual generation costs (s) and the theoretical costs (s*). As a consequence, the "apparent" levels of total factor productivity are (seem) lower. Total factor productivity is (seems) larger when the upstream knowledge industry sells at low costs, closer to s*, its knowledge output, and a larger share of the residual is appropriated by downstream customers that use it to introduce innovations.

Knowledge is a special good with characteristics -strictly contingent upon the structure of the system into which its generation and exploitation take place- that account for the levels and the rates of increase of total factor productivity.

When the generation and exploitation of knowledge do not take place in appropriate contexts, in fact, the case for market failure applies. Knowledge market failure impedes the creative response of firms that try and cope with emerging mismatches between expected and actual product and factor market conditions. Economic systems are not able to organize viable Schumpeterian growth regimes cannot take advantage of the opportunities provided by knowledge and are doomed to adaptive responses that trap them into equilibrium conditions.

When the generation and exploitation of knowledge take place in highly qualified institutional and economic contexts that enable high quality mechanisms of knowledge governance and the limited exhaustibility of knowledge enables its effective accumulation into large and varied stocks of quasi-public knowledge that can be accessed and used at low costs, the cost of knowledge as an output is far below the equilibrium cost of any standard good. When knowledge costs fall below equilibrium levels, the consequent pecuniary knowledge externalities support the creative response of firms caught in out-of-equilibrium conditions and are at the origin of the eventual introduction of innovations and total factor productivity growth.

This dynamics is fully recursive and highly path dependent. Because knowledge externalities are endogenous, systems able to implement and support appropriate and persistent levels of knowledge governance, are able to keep adding the new vintages of knowledge generated at each point in time to the stock of quasi-public knowledge, introduce new innovations that cause new out-of-equilibrium conditions of product and factor markets that in turn stir new waves of creative response with the generation of additional flows of knowledge so as to reduce further its cost and experience persistent out-of-equilibrium conditions.

2.9 THE CAPITALIZATION OF KNOWLEDGE

The advances of the economics of knowledge with the appreciation of the key role of both its limited appropriability and exhaustibility have important consequences on our understanding of the production process and of the role of the production and capitalization of knowledge.

In recent years several attempts have been made to directly estimate the spending on assets that are ignored or imperfectly covered in the current firm-level (as well as national income) accounting practice. These assets consist of not only of technological knowledge stocks stemming from the accumulation of R&D expenditures but include a broader array of knowledge types such as employer-provided training, strategic planning by management and reorganization projects in the past, software, advertisement expenditures, reputation, brand recognition (Audretsch and Link, 2018). These studies have made two main findings; firstly, official macroeconomic data exclude a large proportion of total investments and assets as a result of a deficient measurement of intangibles, and secondly, R&D accounts for only roughly one half of the total intangible capital (Corrado et al, 2005). Recent contributions (Corrado et al. 2009; Marrano et al, 2009; Rassenfosse, 2017) make considerable progress to extending the list of types of knowledge assets that enter, on the input side, the definition of intangible capital including various forms of economic competencies, innovative property and digitalized information, designs and trademarks (Haskel and Westlake, 2017).

The effort to appreciate and include the value of knowledge stocks on the input side has not been matched by the necessary effort to take into account the role of knowledge on the output side. The capitalization of knowledge output as a financial asset is not properly reflected into the accounting methodologies neither at the firm nor at the national level. The notion of value added is the basic unit of analysis for all growth accounting. The current methodology for the measurement of value added does not take into account as a source the effects of the sale of assets. An example can help to make better clear the point.

Let us first consider the case of a tangible capital good. The production and sale of a tangible capital good such as a machine tool yields a clear statistical record in terms of sales and value added. The purchase of the machine tool by a company yields statistical records that contribute the aggregate statistics on investments.

The generation and sale of an intangible capital good, such as a patent, exerts quite different outcomes in terms of accounting, and growth accounting. The generation of new knowledge is the outcome of a flow of R&D expenditures that are capitalized, on the input side. The new knowledge typically encapsulated in an IPR is accounted as an intangible capital good. Its sale engenders a positive gain that affects profitability, but not sales and value added.

The same example enables to focus a second problematic aspect. The literature assumes that the sale of tangible capital goods is the result of a transaction that takes place in a competitive market so that the price is close to the intersection between marginal and average costs that in turn implies that the factor intensity of the production process is close to equilibrium. The literature assumes that the markets for tangible capital goods are characterized by many actors on the demand and the supply side. Moreover, the literature assumes that the tangible capital good is –quite- homogeneous so that many producers can supply other capital goods that share the basic properties and functions. The assumption about competitive conditions in the markets for knowledge cannot apply. Each patent represents a unique product with highly specific and idiosyncratic characteristics that cannot be replaced by –almost- any other piece of knowledge. The owner of a patent holds evident monopolistic power. As a consequence, the price of the knowledge item is far from any standard equilibrium condition.

The capitalization of knowledge raises a set of problems. The sale of a patent by an individual or a company raises similar problems. In both cases the exploitation of knowledge is not recorded by standard accounting as part of value added. The sale of firm whose value consists only in the financial asset that capitalizes the generation of knowledge represents the extreme case. Yet this is typically the case of start-ups supported by venture capitalism. The revenue of the financial transaction that transfers the intellectual property rights or the knowledge intensive equity from an agent to another does not add to the figure of value added. Total factor productivity measures are undermined by the missing appreciation of current accounting procedures of the capitalization of knowledge.

All the transactions of the equity of private firms that take place via mergers and acquisitions at prices that are larger than the book value make evident the effects of the capitalization of knowledge. It is clear the market value of the firm includes in most cases the capitalization of knowledge inputs that are accounted as intangible assets. The gap between the book value that includes the capitalized knowledge inputs and the market value reflects the difference between the value of knowledge inputs and the value of knowledge outputs. The value of knowledge output clearly exceeds the value of knowledge inputs where both are capitalized: the latter ex ante and the former ex post.

The capitalization of knowledge output has even more evident effects when financial transactions in the stock markets are taken into account. Here the notion of Tobin's q plays a central role. Tobin and Brainard (1977) introduced the q ratio following exactly the same approach followed by Robert Solow to introduce the notion of total factor productivity. The q ratio in fact compares an expected equilibrium value of a share with the actual one. The expected equilibrium value of a firm (the price of a share times their number) should be fully reflected by the replacement costs of its assets (including the intangible assets and specifically the knowledge inputs capitalized as intangible assets). As a matter of fact, the actual value of a public company as calculated from the value of its shares traded in the stock exchange differs often radically. Specifically, the q ratio is >1 when the market value is larger than the book value. The discrepancy between market and book value is determined by the profitability of the firm. The Tobin's q is >1 when profitability is above equilibrium levels and <1 when its profitability falls below equilibrium levels.

The dynamics is quite obvious: the market value of the shares of firms with profitability levels above the equilibrium levels are purchased by investors. The rise of the market value takes place until its profitability, measured by the ratio of profits to the market value, matches equilibrium levels. Assuming that product and factor markets are in equilibrium the introduction of innovations is the single driver of profits above equilibrium levels.

When the role of knowledge is taken into account as the necessary condition for the introduction of innovations, Tobin's q provides a reliable measure of the capitalization of knowledge. Tobin's q in fact identifies the implicit value of knowledge capital that is not properly accounted by the replacement costs of firms' assets as the difference between the replacement costs of firms' assets and the market value of a public company. Here the analogy between Solow's TFP and Tobin'q is clear. The value of knowledge capital is the residual.

When a public company is able to earn extraprofits stemming from the successful introduction and exploitation of technological and organizational innovations, investors are keen to buy its shares in the stock market. The price of the shares and hence the market value of the firm increase until its profitability, i.e. the ratio of the extraprofits to the new increased market value, matches average levels. Profitability is brought back to equilibrium levels. The dynamics of capitalization in the stock markets, in other words, enables to restore equilibrium conditions.

When perfect conditions of competitive equilibrium apply, even after the introduction of an innovation, the immediate entry of new competitors and imitators in the product and factor markets would impede the appropriation of the benefits of innovations at the firm level and sweep away all extraprofits. Hence the relationship between innovation and profits would not take place. When, instead, innovators can take advantage from transient monopolistic power and appropriate a share of the benefits of innovations in terms of profits, their profits increase and the ratio of profits to the book value becomes larger than the equilibrium levels. The basic conditions of equilibrium at the system level are altered and out-of-equilibrium conditions risks to spread through the markets. The stock markets restore equilibrium conditions (Antonelli and Teubal, 2008 and 2010; Antonelli and Colombelli, 2011a).

This conceptual relationship between market value and innovation-cum-knowledge has been much investigated. Starting with the seminal work of Griliches (1981), an array of works has related Tobin's q with the intangible capital that enables firms to generate technological knowledge and introduce technological and organizational innovations that reduce costs and increase output and, consequently, the profitability that stems from the appropriation of the stream of rents secured by knowledge exploitation (Cockburn and Griliches 1988; Coad and Rao, 2006).

Financial markets, with the dynamics of capitalization, provide a remedy to the out-of-equilibrium conditions engendered by the generation of knowledge below its equilibrium levels –because of the effects of pecuniary knowledge externalities in the recombinant generation of knowledge- and substitute for the missing equilibrium in product and factor markets. The capitalization of knowledge in financial markets absorbs the out-of-equilibrium conditions engendered by the introduction of innovations. Capitalization converts 'extraprofits' in 'extracapital' and in so doing restores equilibrium conditions in the relationship between actual profits and equilibrium rates of return.

As a consequence, however, it is clear that the capital endowments themselves become endogenous. Now the market value of the company depends upon its profits. In equilibrium conditions on the product and factor markets the relationship works the other way around: the profits of the firm depend upon the price of capital. When the introduction of innovations alters the equilibrium conditions of competitive markets a divide and a discrepancy widen between the market value and the book value of a company, both private and public, until the dynamics of capitalization in the stock markets enables to restore equilibrium conditions as described.

As a matter of fact, the working of financial markets transforms total factor productivity (TFP) into knowledge capital. The capitalization of knowledge contains and provides valuable information on the actual amount of profitable technological innovation introduced by each firm that is above the levels captured by R&D and patent statistics and converts it in a reliable measure of the actual worth of the knowledge capital that has not been properly accounted because of the difference between the cost of knowledge –including its stock- and its actual contribution to output. The estimated value of the stock of knowledge capital provided by Tobin's q is able to capture the correct "equilibrium" amount of knowledge. At the same time, however, it reduces the levels of total factor productivity. The customers of the knowledge capital -typically the take-over of a high tech startup- record the purchase of an intangible capital that has been augmented by the appreciation of the knowledge capital. As a consequence, the amount of capital in downstream users increases with the ultimate effects of downsizing the residual and hence the levels of total factor productivity.

The additional market value of the firm measures directly the gap between the capitalized value of the knowledge capital based upon knowledge inputs and the actual market value that is able to capture the actual total value of the knowledge output. Tobin'q is a consistent measure of the gap between the value of the capitalized knowledge inputs and the capitalized value of the knowledge output. The Tobin's q becomes, consequently, a reliable measure of the total output of the knowledge generation process that, because of the effects of the limited exhaustibility of knowledge is larger than expected in equilibrium conditions.

Tobin's q substitutes the TFP. The two measures can be considered two alternative indicators of the effects of out-of-equilibrium conditions engendered by innovation. As a matter of fact, both the Tobin's q and the TFP reflect and measure the effects of the introduction of innovations on the equilibrium conditions of product and factor markets. More specifically, as Antonelli and Colombelli (2011a) show, the out-of-equilibrium conditions engendered by TFP, are the cause of Tobin'q values. Yet the working of financial markets, measured by the Tobin's q, leads to the actual substitution of TFP. The larger are the Tobin's q and the lower are the TFP levels for downstream users, i.e. the rest of the economy.

Firms able to generate new technological and organizational knowledge at costs below equilibrium because of its limited exhaustibility and appropriability, to use it to implement a creative response to out-of-equilibrium conditions in their product and factor markets and introduce technological and organizational innovations and to appropriate their economic benefits, are able to produce more output with given levels of inputs. Output levels that are larger than expected equilibrium levels are the cause of performances above equilibrium levels and specifically larger profits. Profits above equilibrium engender the increase of the market value of the shares of the innovative firm (Antonelli, 2017a).

The additional knowledge capital reflected in a given time interval by the corresponding increase of the levels of Tobin's q in the same unit of time should be accounted as an intrinsic component of the total output of a firm. The inclusion of knowledge capital on the output side becomes a key issue not only for growth accounting, but a necessary and indispensable step to grasping the capitalization of knowledge output, intrinsically and systematically larger than knowledge inputs, as the distinctive characteristic of the knowledge growth regime. The analysis of the capitalization of knowledge as an output made possible by the Tobin's q reveals the limits of the accounting procedures of the intangible assets as inputs that are being – slowly- adopted by national accounts following the methodology implemented by Corrado et al. (2005 and 2009).

The accumulation and exploitation of knowledge as capital becomes the distinctive character of the knowledge economy. The knowledge economy is characterized not only by the production and use of knowledge intensive business services, but also by the exploitation and valorization of knowledge as a critical component of total capital.

The assessment of the economic value of the stock of knowledge and its incremental addition is based upon financial markets with five distinct mechanisms: i) the trade of knowledge as an asset in the quasi-markets for knowledge; ii) its –indirect- valorization by means of the Tobin's q[3]; iii) the merger and acquisition by corporations of start-up companies after they entered the stock market and became public companies by means of IPO that enable to valorize their knowledge content; iv) the capitalization of

[3] Current attempts to take into account the role of intellectual capital do not seem to take into account the foundations of growth accounting (Ståhle, Ståhle and Lin, 2015).

extraprofits as intangible assets; v) the merger and acquisition of existing corporations that enable to cash the intangible components of their stock.

The limits of current accounting methodologies to include the revenue stemming from the generation of knowledge and its exploitation as a financial asset undermine the empirical foundations of the current analyses on the decline of output growth and total factor productivity increase.

The exploitation of knowledge, by means of its capitalization and transformation in financial assets, questions the basic accounting methodologies from two viewpoints (Byrne et al., 2016):

i) The capitalization of knowledge complemented by -transient-monopolistic rents leads to augmented levels of capital, that, when are reflected in accounting procedures on the input side, increase the levels of the theoretical output and hence reduces the estimated levels of total factor productivity. The outcome is quite paradoxical: the faster are the rates of introduction of new technologies and the larger their effects on the levels of capitalized intangible assets, and the larger will be the equilibrium level of output, hence the lower the rates of increase and the levels of total factor productivity.

ii) The generation of knowledge now produces directly wealth rather than income. The inclusion in value added based national accounts of the wealth triggered by the generation and exploitation of new knowledge as a financial asset does not take place and yet it is strictly necessary. The total output of an economic system should include the knowledge that has been generated both explicitly as the result of a dedicated activity and implicitly as the outcome of learning process (Stiglitz, 1987). So far, this inclusion takes place in a cursory way. This omission reduces further the estimated levels of total factor productivity.

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3. THE NEW KNOWLEDGE INTENSIVE DIRECTION OF TECHNOLOGICAL CHANGE

ABSTRACT
THIS CHAPTER ELABORATES A UNIFYING APPROACH TO THE DETERMINANTS OF TECHNOLOGICAL CHHANGE THAT BRINGS TOGETHER THE FRAMEWORKS OF THE SCHUMPETERIAN CREATIVE RESPONSE, THE INDUCED TECHNOLOGICAL CHANGE, THE DEMAND PULL AND THE LOCALIZED TECHNOLOGICAL CHANGE. THE INTEGRATED FRAMEWORK ENABLES TO EXPLORE THE EFFECTS OF ABSOLUTE AND RELATIVE TECHNOLOGICAL CONGRUENCE ON THE DIRECTION OF TECHNOLOGICAL CHANGE AND TO UNVEIL ITS KNOWLEDGE AND LABOR INTENSIVE AND FIXED CAPITAL SAVING BIAS. THE CORRECT ACCOUNT OF THE ROLE OF KNOWLEDGE AS BOTH AN INPUT AND AN OUTPUT ENABLES TO UNDERSTAND THAT THE ACTUAL DIRECTION OF TECHNOLOGICAL CHANGE AT WORK IN THE

KNOWLEDGE GROWTH REGIME IS BIASED TOWARDS THE USE OF CREATIVE LABOR THAT IS CAPITALIZED AS AN INTANGIBLE ASSET.

KEY WORDS: CREATIVE RESPONSE; LOCALIZED TECHNOLOGICAL CHANGE; INDUCED TECHNOLOGICAL CHANGE; DIRECTION OF TECHNOLOGICAL CHANGE; TECHNOLOGICAL CONGRUENCE; KNOWLEDGE INTENSITY.

3.1 INTRODUCTION

The appreciation of the advances of the economics of knowledge enables to try and integrate into a unifying framework the Schumpeterian notion of technological innovation as a creative response and the model of localized and directed technological change.

Their integration provides enables to accommodate in a single framework different and yet complementary attempts to elaborate an endogenous account of the introduction of technological change driven by the availability of technological knowledge. These approaches, in fact, share the basic intuition that technological change is endogenous as it is the outcome of the technological response of firms caught in out-of-equilibrium conditions contingent upon the access and use conditions of the stock of knowledge accumulated because of its limited exhaustibility and made available at the system level by its limited appropriability.

3. 2. THE CREATIVE RESPONSE

According to Schumpeter (1947) firms in equilibrium conditions are reluctant to try and innovate. The introduction of innovations requires the allocation of relevant resources in activities that are characterized twice by high levels of risk close to uncertainty: i) the risk intrinsic to knowledge generation; and ii) the risks of appropriation of the benefits triggered by the consequent introduction of innovations. The undertaking of innovative activities is not compatible with normal profits. Firms are urged to try and innovate when they are caught in out-of-equilibrium of their product and factor markets.

The irreversibility of the capital stock planned at time t exposes firms to an out-of-equilibrium condition when either factor or product markets do not match the expected plans. Firms need to cope with the new and un-expected conditions of product and factor markets. This can be dome either adjusting their techniques or changing their technologies. The actual conditions for the generation of new knowledge as determined by the quality of learning processes, the size and variety the stock of quasi-public knowledge, its access conditions shaped by the quality of the knowledge governance mechanisms, play a central role in assessing the outcome of the response whether it can be actually creative or adaptive. If and when no knowledge externalities are available and the stock of competence accumulated by means of learning processes is small, and switching costs are low, the response of firms is likely to be adaptive as they can only move on the existing map of isoquants. The introduction of technological changes is a viable alternative to adaptive technical changes only when relevant knowledge externalities are available and learning processes are effective so that knowledge costs are below equilibrium levels. The introduction of technological changes is a creative response to the mismatches between planned and actual conditions of factor and product markets that can only take place when and if sufficient knowledge externalities and effective learning processes, that make the generation of new technological knowledge possible at costs below equilibrium with the consequent introduction of technological changes, are available (Antonelli, 2017a and 2018c).

The model of the creative response has relevant overlapping with the demand pull and induced technological changes approaches. According to the induced technological change approach firms introduce new technologies in order to cope with the changes in factor markets. In the induced technological change approach in fact firms are pushed to innovate in order to save on the factors that are becoming more expensive: technological change is both endogenous and intrinsically biased (Marx, 1867; Hicks, 1932; Ruttan, 1997, 2001, Acemoglu, 2001, 1998; Aghion and Howitt, 2006).

In the demand pull approach, the increase of the demand pulls the introduction of innovations. Firms are pushed to introduce technological changes by the increase of the demand for their products by means of the increase of productivity rather than the increase of inputs (Kaldor, 1966, 1967, 1972, 1981; Schmookler, 1966).

In both cases the introduction of innovation is regarded as a response contingent to the changing conditions of the context into which firm are placed. The two traditional approaches share the view that technological change takes place when firms are exposed to out-of-equilibrium conditions. Firms are not expected to introduce innovations in equilibrium conditions. Out-of-equilibrium conditions are the cause of technological change as much as the introduction of technological change is itself the cause of out-of-equilibrium conditions.

The two traditional approaches share another key aspect: both are based upon the assumption that firms are not able to cope with out-of-equilibrium conditions with standard technical change i.e. with the adoption of existing techniques available in the existing maps of isoquants. In both cases in fact firms try and react to the changes of their markets with changes that reshape the maps of isoquants.

The two traditional approaches acknowledge the central role of knowledge. In the original Marxian approach to induced technological change, little elaborated by the following literature, technological knowledge plays a central role. According to Marx, when wages increase, capitalists are able to appropriate the knowledge generated by learning by doing and learning by using by workers, articulate it with the assistance of scientific labor, and embody it in new vintages of capital goods that substitute labor. The demand pull triggers its positive effects in terms of eventual introduction of technological innovations only if the additional demand for the product of the firm helps increasing the levels of the division of labor, which in turn enables higher levels of specialization that improve the competence of firms and their command of the enhanced generation of technological knowledge that finally leads to improving the efficiency of the production process.

The framework of the localized technological change can accommodate the analysis of introduction of innovations as a creative response to the changing conditions of product and factor markets integrating the induced and the demand pulled technological change approaches within a unifying framework that enables to appreciate the central role of knowledge as the key factor in accounting for both the direction and the rate of technological change.

3.3. LOCALIZED TECHNOLOGICAL CHANGE AS A CREATIVE RESPONSE

THE FRAME

Let us start recalling the basic elements of the localized technological change approach to understand how and why technological change, induced by changing levels of factor costs that myopic firms have not been able to anticipate, can trigger the creative response of firms to both changes in product and in factor markets as to change both the position and the slope of the map of isoquants (Antonelli, 1995, 2003, 2008).

According to its original formulation, technological change is localized by the source of competence and knowledge that is acquired mainly if not exclusively by means of learning by doing, learning by using and learning by interacting (Arrow, 1962b). The localized origins of such 'tacit' knowledge limit the mobility of firms and the ray of possible techniques that firms can use. As Atkinson and Stiglitz (1969) note "knowledge acquired through learning by doing will be located at the point where the firm (or economy) is now operating" (p. 574).

In this approach, in order to introduce technological innovations such firms rely mainly if not exclusively upon a form of localized technological knowledge based upon the skills of the workforce active at the plant level and implemented in the interactions with customers and clients. Localized technological knowledge has been generated, primarily, out of learning activities. It is the result of bottom-up processes of induction based upon tacit knowledge that is eventually implemented and codified. Firms can improve only the technologies they have been able to practice and upon which they have acquired a distinctive competence that is characterized by an idiosyncratic and narrow scope of application.

Localized technological knowledge cannot be easily stretched and applied far away from its original locus of accumulation. These firms are not able to command a broad and codified base of scientific knowledge and to extract out of it, with the typical top-down deductive procedure, a wide range of new possible applications that can characterize all the range of production techniques represented on the full isoquant (Atkinson and Stiglitz, 1969; Antonelli, 1995).

Nelson and Winter have made important contributions to the theory of localized technological change establishing a clear link to the model of induced technological change. In their model firms, induced to a local search by disappointing levels of profitability, introduce directed technological innovations: "When firms check the profitability of alternative techniques that their search process uncover, a higher wage rate will cause certain techniques to fail the 'more profitable' test that would have 'passed' at a lower wage rate and enable others that to pass the test that would have filed at a lower wage rate. The latter will be capital intensive relative to the former. Thus, a higher wage nudges firms to move in a capital intensive direction compared with that in which they would have gone." (Nelson and Winter, 1974: 900). In their model a local search, induced by changes in factor prices that engender a fall in profitability and limited to the surroundings of existing techniques, uncovers new superior technologies consisting in one single fixed coefficient that is able to make much a more intensive use of the factor that is locally more abundant.

Localized technological change is inherently biased by the role of learning processes in the generation of technological knowledge. The creative response in fact is possible only when and if firms have the actual opportunity to generate knowledge at costs that are below equilibrium taking advantage of the competence at the tacit knowledge that has been accumulated by means of the localized learning processes. The capability to generating technological knowledge in turn becomes itself a factor that shapes not only the rate but also the direction of localized technological change (David, 1975; Antonelli, 1995, 2003 and 2008).

Because of irreversibility, production factors can be altered only by means of dedicated activities and consequent switching costs, which keep firms within a limited technical area and prevent significant changes being made to the input mix. The very amount of resources that would be necessary to perform the switching activities can be used to generate new technological knowledge and introduce new technologies that enable firms to cope with the new conditions of factor markets. Hence firms can consider to implement a creative response only when they are able to generate new technological knowledge based upon the valorization of tacit knowledge with formal R&D activities, coupled by the access and use the stock of quasi-public knowledge, at costs below equilibrium.

The appreciation of the role of learning and more generally of knowledge externalities in the generation of knowledge enables to integrate into a unifying framework the localized technological change approach, the creative response and the induced and demand-pulled approaches.

A GEOMETRIC EXPOSITION

Let us start with a standard Cobb-Douglas production function and its cost equation:

(1) $Y = K^a \; L^b$
(2) $C = rK + wL$

where Y denotes output in value added, K stands for capital and L for labor, **a** and b denote respectively the output elasticity of capital and labor, under the standard assumption of constant returns to scale; r measures capital rental costs and w unit wages.

We assume that firms in equilibrium condition in factor markets are exposed to an un-expected change. They need to adjust to the new factor market conditions. Such adjustment is not free: it requires some adjustment activities.

Figure 3.1 shows how a compensated change in relative factor price affects the viability of the previous equilibrium A. It is clear that firms cannot stay in the old equilibrium point A: the firm produces at costs that are well above the new equilibrium levels.

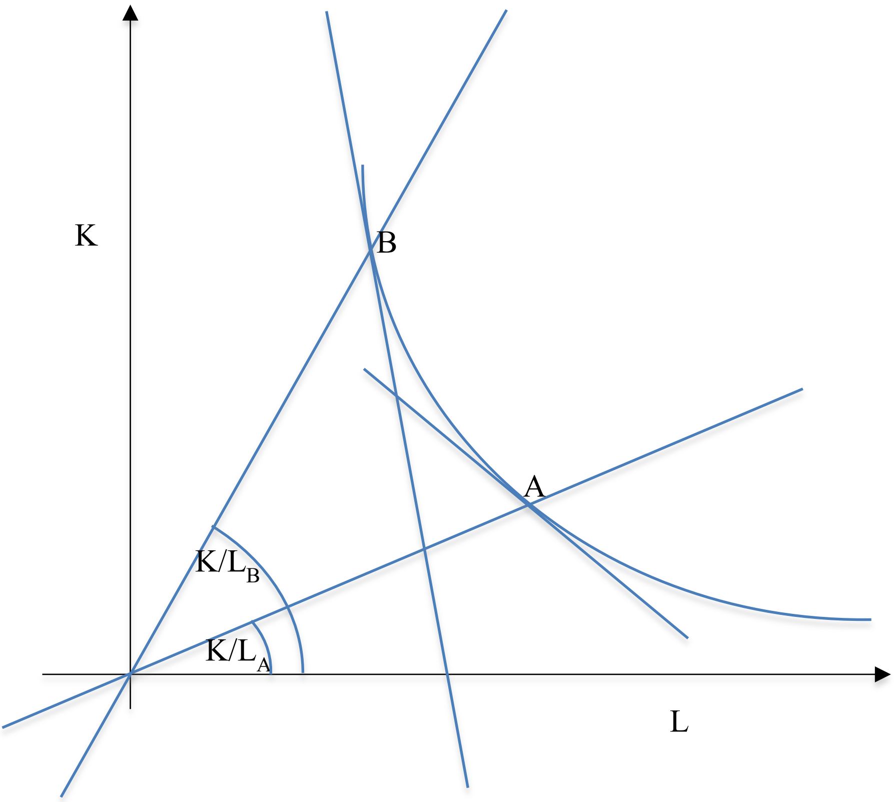
The firm can either change the technique and move to B or change the technology by means of the introduction of technological innovations, so as to find a new equilibrium in the proximity of the isocline KL_A. The outcome will depend upon the levels of switching costs, that is the amount of resources that are necessary to perform all the activities that enable the firm to move from A to B compared to the amount of technological changes that can be introduced with the amount of resources that are necessary to switch.

Because of the mismatch between expectations and the actual conditions in the markets place, and the irreversibility of the technique that had been selected according to the previous factor market conditions, technical change, defined as the movements upon the existing map of isoquants, is expensive. In such conditions the introduction of a creative response, based upon the generation of new technological knowledge and the introduction of innovations, as opposed to the passive adjustment on the existing map of techniques, can become a viable alternative.

In Figure 3.1 we see that the new equilibrium condition B requires a change in the factor intensity from K/L_A to K/L_B. These adjustments require some switching activity. Switching activities are resource consuming. According to the characteristics of the switching activities we can identify the amount of resources necessary to move from A to B along the existing maps of isoquants.

INSERT FIGURE 3.1 ABOUT HERE

FIGURE 3.1 THE INDUCEMENT OF LOCALIZED TECHNOLOGICAL CHANGE



Firms can now explore the possibility of introducing a new technology with a clear budget constraint. The introduction of a new technology requires dedicated inputs in terms of new knowledge. The cost of knowledge plays a central role. For a given budged -defined by the levels of switching costs- the amount of innovation that a firm can actually introduce depends upon the costs of knowledge. When and where the costs of knowledge are low and below equilibrium levels, the firm can implement a creative response. The cost of knowledge in turn depends upon the size and variety of the stock of technological knowledge available in the system, its access and use costs determined by the quality of the knowledge governance mechanism, and the learning capabilities of each firm.

INSERT FIGURE 3.2 ABOUT HERE

This approach enables to confront agents and economic systems with respect to the shape of their frontier of possible adjustments. The levels of switching costs that are necessary to move on the existing map of isoquants are regarded as a constraint. The vertical axis identifies the output that can be produced bearing the given level of switching costs. The horizontal axis identifies the output that can be produced using the resources that are necessary to switch, to fund the generation of new knowledge and introduce technological innovations. Figure 3.2 compares three systems (as well as three firms) with respectively low, medium and high knowledge costs. Figure 3.2 shows the case of alternative distances on the horizontal axis reflecting different levels of output produced with different knowledge costs and innovation capabilities, such as OD, OE, OF, that can be obtained by means of the same level of resources that are necessary for all agents to switch from A to B. Agents able to reach OF are able to generate a larger output with the introduction of innovations for a given amount of inputs, than agents that cannot move any farther than D.

INSERT FIGURE 3.3 ABOUT HERE

As it is shown in Figure 3.3 the solution is found by means of the maximization of the revenue stemming from the adjustments to the changes in factor markets that have driven the firm out-of-equilibrium. The result of the maximization is found with the help of the frontier of possible adjustments defined by the output levels that can be produced with the introduction of either switching or innovation and the map of isorevenues. The slope of the isorevenues is necessarily =1 as we assume competitive markets with homogenous products and the price does not reflect whether firms did switch or innovate. The standard tangency between the isorevenues and the largest frontier identifies the best combination of switching and innovation that can be attained.

FIGURE 3.2 ALTERNATIVE SHAPES OF THE FRONTIER OF POSSIBLE ADJUSTMENTS

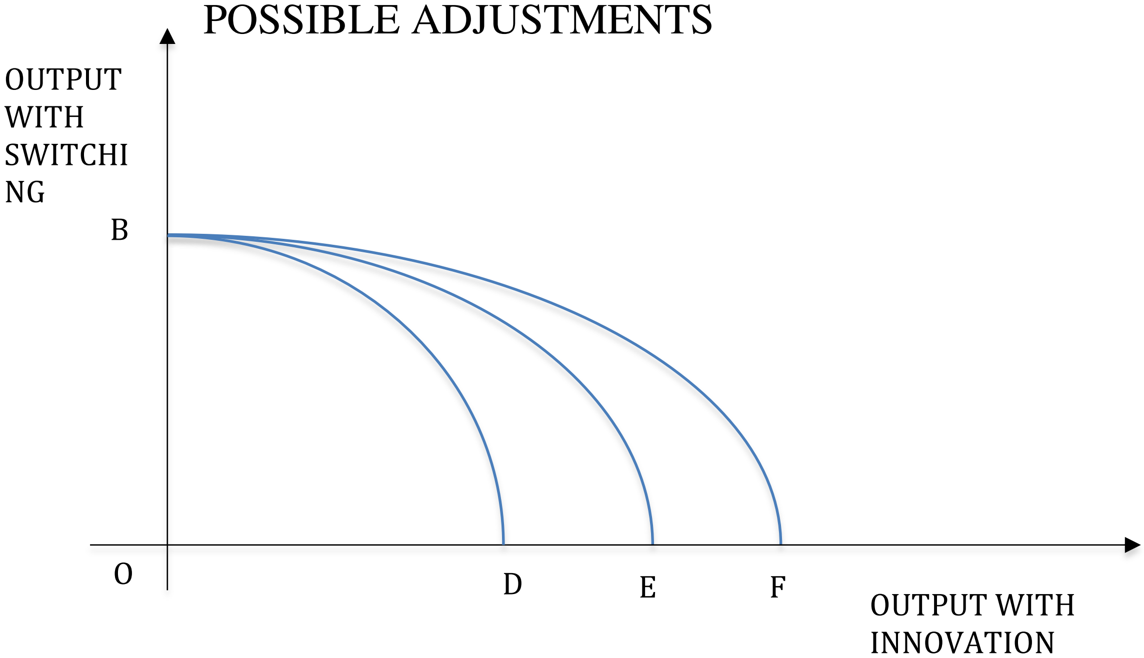
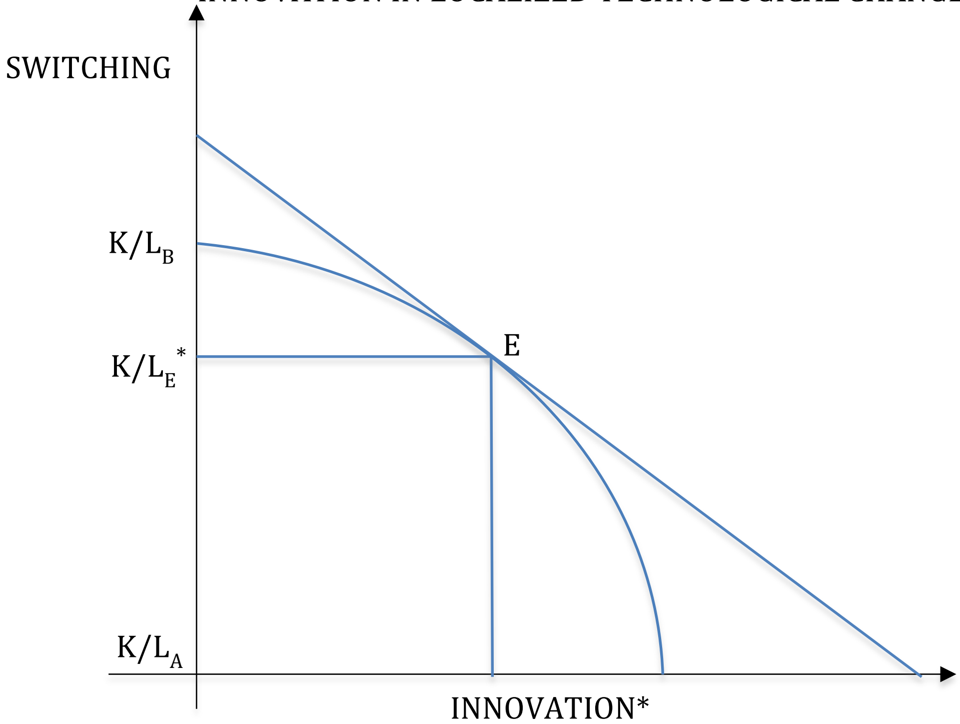


FIGURE 3.3 THE EQUILIBRIUM MIX OF SWITCHING AND INNOVATION IN LOCALIZED TECHNOLOGICAL CHANGE



INSERT FIGURE 3.4 ABOUT HERTE

Figure 3.4 provides a synthesis of the results of our analysis. We see in fact that firms exposed to unexpected changes in factor prices (the new isocost is tangent to the old isoquant in B far away from A) cannot stay any longer in the old equilibrium point A where the old isocost was tangent to the old isoquant. A response is necessary. Because of switching costs, however, firms cannot easily move from A to B.

The change in the slope of the isocost engendered by the compensated increase in unit wages and the decline of the rental cost of capital however can be coped with by means of the generation of new technological knowledge based upon the valorization of tacit knowledge acquired by means of localized learning processes, both in doing and in using, based upon the technique defined by the factor intensity of the previous equilibrium conditions and the access to the knowledge externalities.

Firms can implement a creative response and change their technologies under the constraint of remaining in the technical surrounding of the previous technical factor intensity so as move along an isocline. According to the relative ease of switching and the technological opportunities based upon the competence acquired by means of localized learning processes and knowledge externalities available in the system, firms can try and generate a new localized technology, i.e, a new map of isoquants that enables them to minimize the amount of switching. In order to restore the equilibrium condition, the new technology should enable firms to reach the new isocost (such as in C and D) and possibly go beyond. All solutions beyond the new isocost (such as in C1 and D1) in fact identify the actual introduction of new superior and localized technologies that enhance the shift efficiency of the firm.

FIGURE 3.4 THE LOCALIZED INTRODUCTION OF TECHNOLOGICAL CHANGES

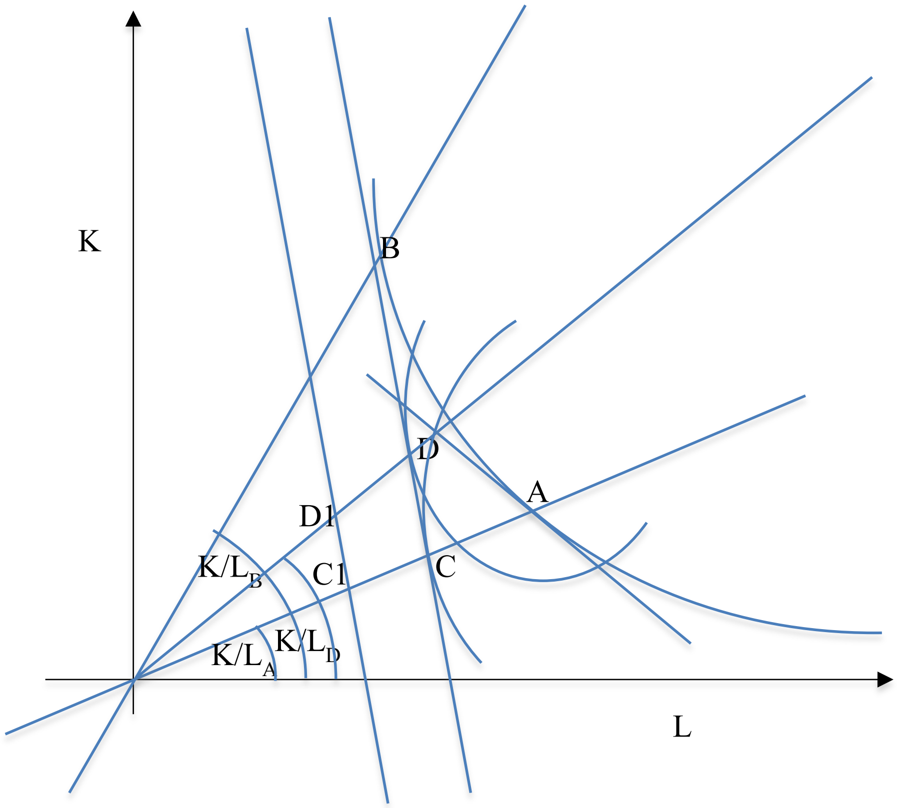


Figure 3.4 shows that when the irreversibility of production factor is very high and learning is fully localized, the direction of localized technological change along the trajectory K/L_A is labor intensive. The analysis of the equilibrium conditions makes the point clear.

A standard textbook economics setup of the analysis of the equilibrium conditions helps grasping the point. Equilibrium is found when:

(3) $\frac{w}{r} = \frac{\beta}{\alpha}\frac{K}{L}$,

With respect to eq.3 it is evident that the increase of labor output elasticity is the single possibility left to firms that try and cope with the increase of wages and cannot change the techniques in place as defined by the ratio K/L. A fully localized technological change is labor intensive.

The implications are far reaching especially if we assume the long term perspective of increasing levels of wages. When wages increase and firms, that in the standard substitution process would try and reduce the amount of labor and increase the amount of capital, try and elaborate a creative response, provided they are able to access and use knowledge at costs below equilibrium, especially when learning processes play a central role in the generation of new technological knowledge and consequently in the introduction of innovations, cannot introduce but directed technological changes biased towards increased levels of output elasticity of labor.

At a closer analysis it becomes clear that the creative response based upon localized technological change is intrinsically knowledge intensive. The introduction of new technologies can take place, in fact, only if firms are able to generate new knowledge, based upon localized learning processes.

The augmented level of wages that is -in a historical perspective- at the origin of the process can be reconciled with the viability of firms by the increased levels of efficiency that in turn are made possible by the larger amount of knowledge actually available to the production process. Workers contribute the process participating into the generation of new knowledge based upon their own learning processes. From this view point wages are actually efficiency wages (Stiglitz, 1974; 1987). Their marginal productivity includes the participation to both: i) the production process and ii) the knowledge generation process. After the creative response based upon the introduction of localized technological change we see that: i) the knowledge content is larger as well as, ii) the productivity levels are larger because knowledge costs are below equilibrium levels.

SYNTHESIS

The analysis of the creative response based upon localized technological change enables to identify the central role of knowledge as the enabling factor of the creative response. In the localized technological change approach to the creative response, knowledge exerts two central roles: i) it is the necessary condition for the creative response to take place, and ii) it shapes the direction of technological change. Let us consider them briefly in turn.

Technological change can be introduced as a creative response to unexpected changes in product and factor markets provided that firms are able to rely upon knowledge that can be generated at costs below equilibrium. The Schumpeterian creative response can take place only if relevant knowledge externalities enable firms to access and use the stock of knowledge and are able to command relevant learning processes. The mismatches between expected and actual product and market conditions, the rise of the cost of inputs as in the induced technological change approach and the increase of the demand for the products of the firm, can actually lead to the introduction of new technologies only if firms can generate new knowledge at costs that below equilibrium levels and use it to introduce technological innovations.

The Schumpeterian notion of creative response enables to accommodate in a single unifying framework the standard tools of the economics of endogenous technological change: i) the localized technological change approach, ii) the induced technological change and iii) the demand pull approach.

The creative response is inherently localized and knowledge intensive. Firms are able to implement a creative response only if they can access and use the stock of technological knowledge accumulated by its limited exhaustibility and made available through the system by its limited appropriability and command effective learning processes that enable to accumulate competence based upon the skills of their creative workers.

The unifying framework provided by the merging of the localized technological change approach with the Schumpeterian creative response and the induced and demand pulled technological change hypotheses enables to highlight not only the central role of knowledge in making the introduction of technological change possible, but also its knowledge intensive direction along knowledge intensive corridors.

The well known argument elaborated by Habbakuk (1962) and implemented by Paul David (1975) about the technological corridors that characterized the US economic growth finds here a new application. According to David (1975) the US economy moved along a narrow technological corridor characterized by the persistent introduction of capital and raw material intensive technologies. Such a technological corridor was induced by the low costs of capital and raw materials and the related accumulation of technological competence in a narrow technical space.

Knowledge has been traditionally embodied in capital goods and could not be traded as a good per se because of the its low levels of tradability. The augmented levels of knowledge triggered by the efforts to generate the new technological knowledge necessary to support the creative response would lead to increased levels of capital intensity. Technological change has been historically capital intensive because the new vintages of capital were the single viable vector of superior technologies.

As long as the contribution of knowledge can be identified, isolated and appreciated, the analysis, implemented so far, enables to identify the actual growth path of economic systems as shaped by the stock of knowledge available and the learning processes that act: i) supporting the generation of new technological knowledge at cost below equilibrium; ii) making the creative response of firms possible, and iii) directing it towards the introduction of new technologies localized in a corridor of highly knowledge intensive techniques.

In advanced economies the transition towards the knowledge economy seems to be characterized by the increasing role of disembodied knowledge made possible by the new mechanisms of tradability of knowledge. The new tradability of knowledge, based upon ICT that enable to trade disembodied knowledge as a service and capitalized equity, changes the mechanism of inclusion of knowledge in the production process and makes better clear the knowledge intensive direction intrinsic to technological change at large (Abramovitz and David, 1996 and 2001).

In sum, the integration of the Schumpeterian creative response into the localized technological change approach helps understanding that the actual direction of technological change is knowledge intensive because the introduction of technological change is itself possible only after the increase of the amount of knowledge a firm and an economic system can command.

3.4 DIRECTED TECHNOLOGICAL CHANGE AS A SOURCE OF COMPETITIVE ADVANTAGE

The introduction of biased technological change directed at increasing the output elasticity of the factor that is locally abundant has strong effects in terms of augmented total factor productivity and competitive advantage. Let us analyze them in turn.

The study of the effects of the direction of technological change on the production function enables to identify the levels of technological congruence defined by the matching of the relative size of outputs' elasticity with the relative abundance and cost of production factors. The introduction of neutral technological change exerts positive -shift- effects on total factor productivity that can be represented by the shift of the map of isoquants. The introduction of biased technological change exerts not only shift effects but also bias effects that can be represented by the change in the slope of the map of isoquants.

The size of the bias effects depends on the matching between the direction of technological change and the relative factor costs. The introduction of labor (capital) intensive technological change in labor (capital) abundant countries increases the levels of technological congruence and has positive bias effects on the levels of total factor productivity. The introduction of labor intensive technologies in capital abundant countries has negative bias effects but can take place, provided that its total effects on total factor productivity are positive: positive shift effects are larger than the negative bias ones.

The total effect of biased technological change on total factor productivity, in fact, is given by the sum of the shift and the bias effects. The sum is positive but either component can be negative. For a given level of shift effects, the introduction of labor intensive technologies in labor abundant countries yields larger results in terms of total factor productivity than the introduction of capital (labor) intensive technological change: larger positive bias effects add to the shift ones. The introduction of labor (capital) intensive technologies in capital (labor) abundant countries may be so relevant to actually exert positive shift effects that are, however, partly compensated by negative bias effects (Antonelli, 2016b).

The induced technological change approach has little explored the effects of the -and the incentives to- the direction of technological change when factor markets are heterogeneous. Factor costs homogeneity is, in fact, the standard assumption in the literature. Yet competitors that rely on the introduction of technological change as a tool of rivalry may be based in heterogeneous factor markets. This takes place when firms have differentiated access to factor markets. The analysis of the effects and incentives to the introduction of biased technological change is much enriched when the assumption of homogeneous factor markets is relaxed so as to take into account the variety of local factor markets,

The globalization of product markets makes the case of the heterogeneity of factor markets compelling: firms based in different countries with different endowments compete on the same product markets. Factor costs equalization should drive input costs towards convergence. Factor cost equalization, however, yields its effects with substantial delays: transient heterogeneity is persistent. As a matter of fact, the heterogeneity of factor costs is found even within national markets, across regions.

Factor costs differentials across regions is especially resilient in intermediary inputs that are themselves the local output of an economic system characterized by relevant pecuniary externalities. The resilience of factor cost differentials becomes endogenous for two reasons: i) local producers enjoy specific conditions that cannot be easily replicated elsewhere; ii) local producers can increase their supply with increasing returns triggered by augmented externalities.

In a static context, with a given technology and hence a given mix of output elasticities, cost heterogeneity among competitors is itself an evident source of competitive advantage: firms select the factor intensity with standard procedures and make a more intensive use of the factor locally cheaper: competitors experience larger costs. In a static context, cost heterogeneity is a source of barriers to entry and profitability for firms that can access inputs at a lower cost.

The strategic search for technologies that are shaped by the effort to take advantage of factor costs differentials that are resilient as they are endogenous and factor costs equalization does not exert its effects, may have relevant effects on the direction of technological change.

The analysis of the strategic direction of technological change impinges upon and yet implements the Schumpeterian framework of oligopolistic rivalry based on the introduction of product innovations. In the Schumpeterian framework firms introduce new products as a tool to improve their competitive advantage with respect to incumbents and newcomers that imitate the previous products. Process innovations play a minor role in the Schumpeterian frame. In the broader context of the strategic direction of technological change, the introduction of process innovations characterized by the intensive use of locally cheaper inputs becomes an additional and actually stronger tool to improve and stretch the duration of the competitive advantage. Incumbents and newcomers can succeed in taking advantage of the uncontrolled leakage of proprietary knowledge but cannot access and use the inputs that are cheaper only in the factor markets of innovators. The competitive advantage based upon the introduction of directed technological change biased towards the intensive use of locally cheaper input is likely to enjoy stronger appropriability and exert more persistent and positive effects on the profitability of innovators than the competitive advantage triggered by the introduction of product innovations.

The study of the introduction of directed technological change on the cost function as the dual of the production function, by innovators based in heterogeneous factor markets, enables to identify, next to absolute technological congruence, the relative technological congruence. Relative technological congruence is found when a technology is biased towards the intensive use of an input that is cheaper in the local factor markets with respect to its costs in the input market into which the competitors are based. This input, however, is not necessarily the cheapest -the cheaper one- with respect to the others included in the production function and or available in the local factor markets.

The intensive use of a production factor that is locally cheaper with respect to other factor markets where competitors are based is a major source of competitive advantage as it increases substantially the actual levels of appropriability. Even if the new knowledge that enables the introduction of the biased technological change spills and imitators can access it freely, its actual implementation yields production costs that are larger than those of the "inventor". The new superior technology, in fact, forces the intensive use of an input that is locally more expensive for imitators than for the innovators. In the imitating region the negative bias effect balances the positive shift effect and reduces the overall positive effects of the spillover in terms of total factor productivity and specifically of total costs. In the innovating country, instead, both the shift and the bias effect can be positive, or in any case their sum is larger, and total cost are much lower.

When technological change is biased, technological spillovers are not neutral. The imitation of a new directed technology forces the use of the very same mix of output elasticities. Imitators based in countries where the new technologies make a more intensive use of the -locally- more expensive input are deemed to experience higher operating costs with respect to innovators that have directed the introduction of new technologies towards the intensive use of the input that is cheaper in their factor markets. Such a biased technological change is the source of persistent and augmented cost asymmetries that trigger actual barriers to entry. The direction of technological change yields a strong competitive advantage in the global product markets. The effects of the introduction of the biased technological change can be fully appropriated by "innovators" (Antonelli, 2016b).

The competitive advantage that is triggered by technologies with high levels of relative technological congruence and make an intensive use of distinctive and rare inputs that are cheaper only in local factor markets and more expensive in other factor markets, becomes itself a powerful inducement mechanism. The direction of technological change is induced by the search of higher profitability instead of higher total factor productivity.

The distinction between absolute and relative technological congruence is quite important both at the system and the firm level. The levels of absolute technological congruence are determined by the relative cost of an input with respect to the cost of the other inputs -that enter the cost function- in a given factor market. The levels of relative technological congruence are determined by the relative cost of an input in a given factor market with respect to its cost in the factor markets of competitors.

The distinction exerts major effects on the inducement mechanism. When absolute technological congruence matters, the innovator is induced to bias its technological change towards the intensive use of the input that is cheaper with respect to the other inputs that enter the production function. When relative technological congruence matters, the innovator is induced to bias technological change towards the intensive use of the input that cheaper in its factor market than in the factor market of competitors.

In this latter case technological change may be directed towards inputs that are not cheaper in the local factor markets than the others included in the production function, but cheaper with respect to the factor markets where competitors are based. The direction of technological change will be intensive with respect to labor (capital or intermediary input) that is not cheaper than the others included in the production function but with respect to the labor (capital or intermediary input) market into which the competitor is based. The bias component of technological change is smaller than in the case of absolute technological congruence.

Innovators have a clear incentive to direct their technology towards the augmented use of the factor that exhibits different costs across factor markets. The bias component of total factor productivity of technological change directed by profitability may be lower than the bias component of total factor productivity that would be obtained by the introduction of a new technology that would increase the output elasticity of the cheapest input. Innovators prefer to increase the output elasticity of an input that is not the cheapest in their factor markets, but relatively cheaper with respect to competitors. In the extreme case innovators may choose to try and introduce a directed technology with a large shift effect and small or actually negative bias effect. Because of the cost asymmetry the bias effect would be smaller for innovators than for imitators.

When technological change is induced by the relative rather than absolute technological congruence, a clear conflict between social and private incentives takes place. Social incentives are maximized by the introduction of technologies directed towards the intensive use of the input(s) that is cheaper than the others included in the production function: in this case, in fact, the bias effect adds to the levels of total factor productivity determined by the shift effect. The innovator, however, may be exposed to the uncontrolled leakage of the proprietary knowledge and the consequent imitative entry of competitors that take advantage of it and reduce drastically the profitability. The search for absolute technological congruence benefits the system much more than the innovator. The search for relative technological congruence, on the opposite, benefits much more the innovator than the system.

The innovator that biases the introduction of technological change towards the most intensive use of the input that is cheaper in h/er factor market but is not cheaper with respect to other inputs included in the production function may increase its profitability more than its total factor productivity, calculated in equilibrium conditions. Imitators can easily access the new directed technology but cannot operate it at the same cost of the innovator. The search for the relative technological congruence increases h/er profitability much more than the overall levels of total factor productivity.

Private incentives induce the introduction of directed technological change with high levels of relative technological congruence as they enable to increase the levels of profitability. The social incentives would induce the introduction of technological change with high levels of absolute technological congruence as they increase the levels of total factor productivity.

The limited appropriability of technological knowledge triggers a contrast between social and private incentives as it may yield the perverse effect of a "wrong" direction of technological change. Actually it is possible to configure the extreme case of the introduction of a biased technological change that increases substantially the profitability of the innovator, as it leads to the intensive use of a rare input that is cheaper in the local factor market than in any other factor market, but has smaller effects on the levels of total factor productivity as it makes an intensive use of an input that is more expensive than the others included in the production function. The shift effect is eroded by the negative bias effect, but only to a limited and minor extent for innovators and to a larger extent for imitators. The profitability in fact is fully appropriated by the "innovator".

Firms have a strong incentive to make a strategic use of the direction of technological change biased towards a more intensive use of locally abundant factors to increase not only their relative technological congruence but also their profitability. The strategic bias of technological change enables to exploit the cost asymmetries engendered by the exclusive access to rare inputs that are rooted in the local factor markets.

The strategic bias of technological change is all the more effective if innovators can rely on distinctive competences accumulated through time that enable them to command their use: the implementation of effective user-producer interactions help to take advantage strategically of factor differentials as much the traditional vertical integration.

When the determinants of factor costs differential are endogenous at the system level, economic policies geared towards the identification and the selective support of the activities that yield intermediary inputs with significant cost differentials with respect to imitators and possible competitors helps to support the direction of technological change towards the use of the inputs that happen to be locally cheaper.

The larger are the cost asymmetries, the stronger their resilience and the lower the appropriability conditions and the larger are the incentives to the introduction of directed technological change with a "wrong" bias with lower levels of absolute technological congruence than it would be possible to obtain in homogeneous factor markets.

The conflict between social and private incentives does not take place when the direction of technological change exhibits high levels of both absolute and relative technological congruence. In this case technological change is directed towards the input that is at the same time cheaper with respect to capital and labor, and cheaper in advanced countries than in industrializing ones. This is the case of knowledge.

3.5 THE KNOWLEDGE INTENSIVE DIRECTION OF TECHNOLOGICAL CHANGE

It is now necessary to reconcile the results elaborated so far about the intrinsic knowledge intensity of the creative response as a localized technological change with the analysis of the direction of technological change (Marx, 1867; Hicks, 1932; Ruttan, 1997 and 2001) selectively revived by the systematic investigations of Daron Acemoglu (1998, 2002, 2003, 2010, 2015).

The aggregate evidence typically based on two-inputs accounting procedures has confirmed for quite a long period of time the capital intensive and labor saving direction technological change. The new empirical evidence in advanced countries highlights the increasing output elasticity of knowledge capital (Autor, Levy, Murnane, 2003).

In advanced countries knowledge capital seems to be the most abundant factor. As such it is cheaper than standard labor and capital and cheaper in advanced countries than in industrializing ones.

The introduction of knowledge intensive technologies in knowledge abundant countries increases the levels of technological congruence and has positive effects on both total factor productivity and profitability. The larger is the knowledge capital intensity direction of technological change and the larger are the levels of technological congruence and the larger is the output with a given budget and consequently the larger are the levels of total factor productivity and the stronger the competitive advantage of knowledge abundant countries.

At a closer analysis, in fact, it becomes evident that the stock of technological knowledge capitalized as a component of the broader stock of capital is the actual abundant factor and the new effective source of competitive advantage for advanced countries. The dynamics of factor cost equalization coupled with the globalization of factor markets has made capital accessible to industrializing countries at cost and conditions that are close to those available to advanced countries.

The relative distribution of the stocks of technological knowledge, instead, is far more asymmetric. Technological knowledge is far more abundant in advanced countries because of the unique availability of large and varied stocks of quasi-public knowledge and the high quality of knowledge governance mechanisms. The actual direction of technological change, as a consequence, is intensive in the use of knowledge capitalized as an intangible and financial asset, rather in fixed capital. The knowledge intensive bias and the fixed capital saving direction of technological change is fully consistent with the search for technological congruence. In a global perspective, knowledge, rather than fixed capital, is the relatively cheaper input in advanced countries.

Imitators based in countries with smaller and less varied knowledge stocks and less effective knowledge governance mechanisms can operate the new knowledge intensive technologies with higher operating costs. The knowledge intensive direction of technological change increases the levels of actual appropriability and yields a strong competitive advantage in the global product markets (Antonelli, 2016b).

According to results of our analysis, the traditional interpretation about the capital intensive direction of technological change, should be reconsidered. In the knowledge economy, in fact, total capital splits into two components: fixed capital and capitalized knowledge. The output elasticity of fixed capital is decreasing while the output elasticity of capitalized knowledge is increasing (Antonelli, 2018b).

The composition of capital is changing. Total capital (See eq.1) splits into two quite distinct components: standard fixed tangible capital and intangible knowledge capital:

(4) $K = FK + TK$

Where FK is the stock of tangible, fixed capital and TK is the stock of technological knowledge.

The standard aggregate Cobb-Douglas production function upon which much macroeconomic analysis is implemented assumes that output Y is produced with constant returns to scale by means of capital and labor. This frame can be enriched with the inclusion of the stock of knowledge as a distinct component of capital in the technology production function:

(5) $Y = A\,(FK^{a}\,L^{b}\,TK^{c})$

where the standard production function is enriched by the inclusion, next to fixed capital (FK) labor (L), of the stock of knowledge (TK). The outputs elasticity of the inputs are respectively a, b and c.

A relevant step forward can be done by impinging on the analysis of the actual character of the stock of technological knowledge as the "general intellect". The stock knowledge, in fact, consists of labor and cannot be separated from it. The generation of all goods including knowledge requires creative labor intensive activities able to master the use, access and eventual recombination of the stock of existing knowledge. Creative labor is at the same time the source and the repository of the stock of technological knowledge. Financial markets, by means of the mechanisms identified by Tobin's q, transform knowledge into intangible capital. The cumulated output of the knowledge generation function where creative labor is the input, enters the technology production function as capital and yet it cannot contribute the production function without creative workers able to use it.

The exploitation of knowledge, however, takes place by means of its valorization as knowledge capital and requires the indispensable intermediation of financial markets. The exploitation of knowledge as a financial asset engenders major rent for agents able to appropriate the tacit knowledge generated by learning processes and to command the recombination of existing proprietary knowledge together with the access to the stock of quasi-public knowledge embedded in the institutional set-up of advanced countries.

These arguments can be framed as it follows:

(6) $TK = f(CL)$

The substitution of eq.6 into eq.5 yields:

(7) $Y = (A)\ (FK^{a}\ SL^{b}\ (CL)^{c})$

Eq. 7 shows that the actual contribution of labor to the production of output at the aggregate level consists of two components: standard labor and creative labor that is eventually incorporated in the stock of knowledge, itself in turn incorporated by standard accounting procedures into a generic capital stock. When the role of creative labor as the ultimate source and repository of the knowledge stock is acknowledged, it becomes clear that the larger is the role of knowledge in the technology production function and the larger the role of (creative) labor. A gap widens between the actual product of (creative) labor and the rules of income distribution. Euler's theorem no longer applies.

The introduction of knowledge intensive technologies that augment the output elasticity of knowledge as an identifiable input should have the direct effect of increasing the role of creative labor in the technology production function. According to the standard assumptions about the relationship between the output elasticity of production factors and their share in income distribution it becomes also evident that the introduction of knowledge intensive technologies should have the ultimate effect to increasing the share of income that should be paid to creative labor.

The correct appreciation of the generation, exploitation and accumulation of knowledge has major implications for growth accounting. Because of the capitalization of knowledge, in fact, the share of income (that should be) paid to creative labor, as the source and repository of the stock of knowledge, adds to the share of income paid to total capital. Knowledge intensive technological change is actually labor intensive. Yet it is accounted as capital intensive because of the capitalization of the product of creative labor.

3.6 CONCLUSION

The twin globalization plays a central role to understand the determinants of this direction of technological change in the knowledge economies. The globalization of financial markets has favored the access of industrializing countries to credit provided by global financial corporations reducing both credit rationing and rates of interest. The spread between advanced and industrializing countries has fallen considerably. Capital is no longer relative cheaper in advanced countries. The globalization of product markets and the delocalization of the manufacturing industry from advanced to industrializing countries include tangible capital goods. The combined effects of the twin globalization with the production of capital goods that takes place in industrializing countries at lower costs and the lower user cost of capital induce the search for a new technological congruence that is able to exploit the relative abundance and lower relative costs in advanced countries of knowledge by means of the introduction of knowledge intensive technologies (Antonelli and Fassio, 2014 and 2016; Rodrik, 2013).

The sharp change of the composition of the capital stock of the S&P 500 firms, where the share of intangible assets in the total asset value jumped from the 16.8% of 1975 to 79.70% in 2005 (Pagano and Rossi, 2009), can be regarded as a reliable clue of the strong knowledge intensive and fixed capital saving direction of technological change.

Knowledge generation is far less footloose than the production of tangible capital goods. Knowledge generation and exploitation is rooted in the size and variety of the stocks of knowledge localized in the web of network and interactions and knowledge governance mechanisms that make the access and use possible at low costs and in the working of financial markets that are able to command its exploitation by means of its capitalization as a financial asset.

The relative abundance of knowledge in advanced countries, where it is rooted in the localized mechanisms of knowledge governance and knowledge accumulation that reduce its mobility across the global economy, has two effects: i) to direct the search for technological congruence towards the increasing knowledge intensity of directed technological changes; ii) to favor the specialization of advanced countries in the generation of knowledge i.e. the production factor that is relatively cheaper and more abundant. The two effects i.e. the new knowledge based international specialization of advanced countries and the knowledge intensity of directed technological change reinforce each other.

In advanced countries the more intensive use of knowledge as the most abundant input increases the levels of technological congruence and bias efficiency with positive -additional- effects on total factor productivity (Antonelli, 2016b).

When the actual role of creative labor as the "repository" of the stock of knowledge capitalized as an intangible asset is acknowledged, the contribution of creative labor as an input both in the generation of new knowledge and in its application to the production of all the other goods is properly identified and the knowledge intensive direction of technological change is taken into account, it seems clear that the actual direction of technological change is intensive in knowledge i.e. the capitalized output of creative labor, rather in fixed capital. The direction of technological change is fixed-capital-saving and intangible-capital intensive from the viewpoint of income distribution, but creative-labor intensive from the view-point of the theory of production. The distribution of the output of knowledge, in fact, does not match the marginal product of creative labor: creative labor receives much a smaller share of its output.

With an aggregate Cobb-Douglas production function the share of revenue paid to capital keeps increasing because of the introduction of labor saving technologies that are expressed by the decline of the output elasticity of labor and the increase of the output elasticity of the aggregate capital. At the same time, however, it is clear that the output elasticity of fixed capital declines while the output elasticity of knowledge as the key input is increasing.

The dynamics analyzed so far are relevant implications:
i) the actual share of income paid to capital is increasing because the share of income paid to knowledge capitalized as a financial asset increases: the increasing share of creative labor adds to the overall share of capital;
ii) the dynamics of the share of income paid to standard labor declines as the result of the segmentation of labor markets. Wages and employment levels of standard labor decline as they are exposed to globalization and to the powerful effects of the factor price equalization. Wages paid to creative labor are more resilient and are actually augmented by the new mechanisms of participation to the rents stemming from the exploitation of knowledge as a capital asset. An increasing share of creative workers is actually paid by means of the direct participation in capital rents and no longer in terms of wage. The distribution of stock options and shares of the equity of start-ups substitutes and/or complements substantially minimum wages;
iii) the capitalization of knowledge blurs the distinction between capital and labor in the distribution of income;
iv) the flows of rents paid to knowledge capital in its two components of knowledge generators (creative labor) and knowledge exploiters (finance) keeps increasing along with the introduction of knowledge intensive technological change. Both income and wealth inequality increase as they are more and more an intrinsic attribute of a globalized knowledge economy based upon the international division of labor where knowledge abundant advanced countries specialize in the production and use of knowledge as a key input and output and capital and low wage industrializing countries specialize in the output of manufacturing industries;

v) the fixed-capital saving of the new knowledge-intensive technological change triggers the decline of investments in tangible capital goods. The fall of investment in tangible capital goods engenders a reduction of aggregate demand that makes uneasy the transition and augments the social and economic fragmentation of advanced economies;
vi) the reduction of the aggregate demand is augmented by the fall of employment in the manufacturing industries.

The dynamics articulated so far has strong self-reinforcing mechanisms. Because of the limited exhaustibility of knowledge, the new flows of knowledge add to the stock of quasi-public knowledge and keep increasing its size. The relative abundance of technological knowledge in advanced countries keeps increasing. The search for technological congruence reinforces the knowledge intensive direction of technological change. The knowledge intensity of technological change leads to the generation of increased flows of technological knowledge that add to the size of the stock of knowledge rooted in the economic systems of advanced countries and make knowledge even cheaper and relative more abundant, inducing further increases in the output elasticity of technological knowledge that reinforces the drive towards the international specialization in knowledge intensive activities. The dynamics of the process is reduced by the fall of the aggregate demand (Antonelli, 2016a and 2018c).

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4. THE DYNAMICS OF KNOWLEDGE GOVERNANCE: SCHUMPETERIAN GROWTH REGIMES

ABSTRACT. THIS CHAPTER ELABORATES THE NOTION OF SCHUMPETERIAN GROWTH REGIMES HIGHLIGHTING THE CENTRAL ROLE OF THE SYSTEMIC MECHANISMS OF GOVERNANCE OF THE INTERACTION AND COORDINATION THAT CHARACTERIZE THE GENERATION, USE AND EXPLOITATION OF KNOWLEDGE AS THE DISTINCTIVE ECONOMIC ACTIVITY THAT IS AT THE HEART OF ECONOMIC SYSTEMS. IT INTRODUCES THE DISTINCTION BETWEEN ENTREPRENEURIAL, CORPORATE AND KNOWLEDGE GROWTH REGIMES ACCORDING TO THE

INSTITUTIONAL DIFFERENCES IN THE KNOWLEDGE GOVERNANCE MECHANISMS.

KEYWORDS: KNOWLEDGE GOVERNANCE; CHANGING MECHANISMS FOR THE GENERATION AND EXPLOITATION OF KNOWLEDGE; SCHUMPETERIAN GROWTH REGIMES; ENTREPRENEURIAL GROWTH REGIME, CORPORATE GROWTH REGIME AND KNOWLEDGE GROWTH REGIMES.

4.1 INTRODUCTION

The integration of the recent advances of the economics of knowledge with the contributions of Joseph Schumpeter enable to frame into a unifying framework the variety of efforts made by the literature to elaborate a systemic interpretation of the general set of interdependent and structured interactions, coordination and institutional mechanisms that qualify the conditions of the economic systems into which the generation, appropriation, exploitation and accumulation of technological knowledge, the introduction of technological and structural change, and long term economic growth may take place.

The notion of Schumpeterian growth regime enables to understand the endogeneity of growth and change. It shows how the organization of the system shapes the governance of the generation, appropriation, exploitation and accumulation of technological knowledge, and hence the stochastic determinants of the creative reaction that leads to the introduction of innovations. Schumpeterian growth regimes enable to focus the analysis on the governance mechanisms by means of which the generation, appropriation, exploitation and accumulation of knowledge change through time and shape the creative reaction that changes firms, product and factor markets, the structural characteristics of the system and its mesoeconomic and macroeconomic dynamics.

The notion of Schumpeterian growth regimes builds upon his attempts to elaborate a systemic and yet dynamic account of the forces at work in economic growth. Schumpeter was in fact, at the same time, well aware of the systemic quality of the Walrasian approach and yet convinced of the need to go beyond its static limitations. Schumpeter repeatedly attempted to implement a systemic frame of analysis that could account for economic growth in the early decades of the 20th century in Europe and eventually in the United States.

The application of the tools provided by the economics of knowledge to a careful reading of *The Theory of Economic Development* and *Capitalism Democracy and Socialism* together with *Business Cycles* and the 1947 essay "*The creative reaction in economic history"* enables to elaborate a "histoire raisonnèe" of the dynamics of the organization of the generation and exploitation of technological knowledge and the introduction of technological change that parallel the shift across different ideal types of growth regimes, based upon the analysis of the changing mechanisms of governance of the limited appropriability and exhaustibility of knowledge as the engine of economic growth (Perez, 2010, Antonelli, 2015a).

The notion of Schumpeterian Growth regimes enables to grasp how the different types of knowledge governance at work affect not only the generation and exploitation of knowledge but also the dynamics of the system, in the product and factor markets and at the aggregate level.

As Schumpeter (1942:43), praising the contribution to economics of Karl Marx, makes clear: "There is however one thing of fundamental importance for the methodology of economics which he actually achieved. Economists always have either themselves done work in economic history or else used the historical work of others. But the facts of economic history were assigned to a separate compartment. They entered theory, if at all, merely in the role of illustrations, or possibly of verifications of results. They mixed with it only mechanically. Now Marx's mixture is a chemical one; that is to say, he introduced them into the very argument that produces the results. He was the first economist of top rank to see and to teach systematically how economic theory may be turned into historical analysis and how the historical narrative may be turned into histoire raisonnée."

The Schumpeterian legacy has contributed to elaborate the notions of "Technological Regimes", "National Systems of Innovation", "Accumulation Regimes" and "Varieties of Capitalism". They share the basic intuition that the introduction of innovations is determined by the systemic characteristics into which firms are embedded. Let us recall then briefly in turn.

The notion of “Technological Regime” has been first introduced by Nelson and Winter (1982) and enriched by the literature that builds upon the founding contributions by Winter (1984; 2006), Malerba and Orsenigo (1997) (Malerba, Orsenigo, 2000). Castellacci and Zheng (2010) provide an excellent synthesis of this literature. According to Castellacci and Zheng (2010) technological regimes are defined exclusively by the industry specific characteristics of the technological environment in which innovative activities take place such as i) the cumulativeness conditions, the extent to which technological activities and performances build upon the accumulated stock of knowledge of each firm; ii) the levels of technological opportunities defined as the likelihood that R&D activities may yield an innovative output; iii) external sources of opportunities defined as the amount of knowledge externalities upon which firms may access; iv) appropriability conditions. As Castellacci and Zheng state: “In a nutshell, the main insight of this approach is that the innovative strategies and activities of enterprises vary greatly across sectors because industries differ fundamentally in terms of the properties of their technological regimes” (Castellacci and Zheng, 2010: 1835).

As it seems clear the notion of “Technological Regimes” explores the determinants of the variance of the rates of innovative activity at the industrial levels with special attention to the differences in the rates of introduction of innovations across industrial sectors. The conditions of knowledge generation and appropriation are regarded as the main determinants of the interindustrial variance of innovative levels. The Technological Regime approach makes an important contribution to the Neo-Schumpeterian literature that had primarily focused the types and intensity of competition and specifically the size of firms and the levels of concentration to account for the variance of innovative activity. The Technological Regime approach, in fact, calls attention on the role of the characteristics of knowledge as the determinants of the rates of innovation. It is worth noting that the Technological Regime approach is fully silent about the systemic determinants of the direction of technological change.

The "National Systems of Innovation" approach elaborated by Lundvall (1992) and Nelson (1993) extends the scope of analysis of the "Technological Regime" approach with a systemic analysis of the mechanisms put in place at the national level to support the generation of knowledge including the role of service industries and especially of the public research system. The role of the University as the prime supplier of basic knowledge is stressed. The interaction between research activities funded and performed by the private sector and the research activities carried out by the public research system is analyzed as a major factor in the generation of new knowledge. The complementarity between the different layers of research activities whether basic, applied or development is analyzed in depth together with the division of labor between the public and the private sector in their implementation (Fagerberg and Sapprasert, 2011).

The "National Systems of Innovation" approach has stirred much research on the mechanisms and channels of knowledge interactions not only between firms and research centers but also among firms. The exploration of the absorption of knowledge spillovers has enabled to identify, next to the horizontal imitation within the same industry, the crucial role of vertical user-producer interactions within value chains (Von Hippel, 1988, 1994, 1998) and the relevance of institutional, organizational, technological, and most importantly, geographic proximity in supporting the access and use of the stock of quasi-public knowledge as an input in the generation of new knowledge (Boschma, 2005). The "National Systems of Innovation" approach enables to apply the mechanisms of the knowledge governance approach (Ostrom, 2010; Antonelli, 2015b)

The "National Systems of Innovation" approach complements the "Technological Regime" focusing the analysis on the role of the systemic interactions in the generation of knowledge and in the introduction of innovations at the national and regional level. Both make an important contribution in calling attention on the role of the systemic conditions that now include a broad array of institutions and procedures, to shaping the generation of knowledge and hence define the rates of innovation activity. Both approaches, however, do not take into account the crucial role of the relationship between finance and innovation and of industrial relations and corporate governance. As a matter of fact, both the notion of Technological

Regimes and the notion of "Systems of Innovation" share the focus on the determinants of the rates of introduction of innovations and do not explore the determinants of the direction of technological change. Neither one has the ambition to explore the systemic conditions of the relationship between the conditions of knowledge funding, generation and exploitation and the macroeconomic performances of the system into which firms are embedded. The "Accumulation Regime" and the "Varieties of Capitalism" approaches contribute to explore these latter aspects.

The notions of "Regulation Mode" and "Accumulation Regime" have been introduced and implemented by the "Ecole de la regulation". According to Aglietta: "For the study of a mode of production will seek to isolate the determinant relationships that are reproduced in and through the social transformation, the changing forms in which they are reproduced, and the reasons why this reproduction is accompanied by ruptures at different points of the social system. To speak of a mode of production is to try to formulate in general laws the ways in which the determinant structure of a society is reproduced." (Aglietta, 1976/2000: 12-13). This approach has been implemented systematically to distinguish between Pre-Fordist, Fordist and Post-Fordist Accumulation regimes. Accumulation Regimes are identified by six key features: i) Monetary and credit relationships; ii) the wage-labour nexus; iii) the type of competition; iv) the relationship between wages and productivity; v) the mode of adhesion to the international regime; vi) the types and tools of economic policy.

The notion of "Accumulation Regime" is far richer and more inclusive than the "Technological Regimes" and the "National Systems of Innovation" approaches. It pays attention to the role of the financial system and generally to the different mechanisms of providing financial resources to innovation activities as well as to the levels of openness of economic systems to international trade and international financial markets. The core of the analysis is provided by the analysis of the macroeconomic coherence between production and distribution processes. The analysis of the relationship between capital and labor, as well as between management and employees plays a central role in the identification of the different "Accumulation Regimes". The notion of "Accumulation Regimes" pays much attention to the wage-labor nexus and to the relationship between wage and productivity. According to Boyer (1988a: 72 and 73) "the wage-labor nexus is defined by a coherent system encompassing the following five components: the types of means of production and control over workers; the technical and social division of labor and its implications for skilling/deskilling; the degree of stability of the employment relation, measured, for example, by the speed of employment duration adjustments; the determinants of direct and social wages in relation to the functioning of labour markets and state welfare services; the standard of living of wage-earners in terms of the volume and the origin of the commodities they consume."

Boyer (1988a and b) makes clear that cumulative growth is possible when real wage income increases with productivity. The actual development of the Fordist "Regime of Accumulation" took place only when real wage income could increase so as to make possible the actual exploitation of the economies of density stemming from the extensibility of knowledge. The distinction between price competition and oligopolistic competition is the third pillar. Price competition among small firms characterized the Pre-Fordist Accumulation Regime" while the Fordist and the Post-Fordist "Accumulation Regimes" were characterized by oligopolisitic competition in final markets, based upon product differentiation where prices are derived from a mark-up applied to average costs, among corporations.

In the analysis of the "Ecole de la regulation" the nexus between production and distribution plays a central role also with respect to the analysis of the introduction of new technologies. The introduction of new technologies is associated to investments following the Kaldorian tradition of the demand pull account of technological change. New vintages of capital embody – necessarily- new technologies. The rate of investment is the key determinant of the rate of innovation.

The poor analysis of the role of technological knowledge and of the innovation process is the main limit of the notion of "Accumulation Regime". New technologies seem to be "on the shelf" *readily available* and at the same time *necessarily* embodied in investments. This analysis may apply to understanding the diffusion of innovations but fails to identify the actual determinants of the generation of new technologies and of the introduction of new technologies.

The strength of the Accumulation Regime approach on the other hand consists in the clear articulation of the relationship between given rates of generation of technological knowledge and introduction of innovations and the actual rates of economic growth. The main contribution of the Accumulation Regime approach rests on the wage-labor nexus. The analysis of the determinants of investments enables in fact to avoid the dangers of technological determinism. The very same wage-labor nexus lead to both the stagnation of the third decade of the XX century and the "trente glorieuses ". The radical difference in terms of growth of output and productivity is found in the shift from profit-led-investment to demand-led-investments. The quest for profits led to shrink wages and consequently aggregate demand with the depressive consequences experienced in the third decade. The increase of wages experienced after WWII supported the rapid growth of aggregate demand that, via the accelerator dynamics, stirred additional investment that could embody new technologies with consistent and self-supporting productivity growth that in turn enabled to further increase the levels of aggregated demand.

The literature on the "Accumulation Regime" has missed to stress the strict complementarity with the demand-pull approach to explaining the rate of innovation. The increase of the demand is expected to augment the extent of the market, hence the division of labor and the levels of specialization that in turn make the accumulation of knowledge and the introduction of innovations not only possible but also more and more convenient.

The "Accumulation Regime" approach however is not able to account for the high levels of variance across regions, countries, industries, and historic time of the rates of generation of new technological knowledge and the rates and directions of technological change that are the ultimate determinants of the growth of output and productivity. This approach contributes to understanding the macroeconomic context into which growth may take place but fails to articulate the analysis of its causes.

Recent advances in this line of analysis, however, enabled to elaborate the "Cognitive Capitalism" approach according to the which advanced economies are centered upon knowledge as the key component of the process of accumulation and valorization of capital (Vercellone, 2003 and 2006).

The Cognitive Capitalism approach calls attention on the role of learning by doing and learning by using in the generation of knowledge nested into the capitalization of knowledge as a financial asset and provides relevant contribution to articulating an analytical apparatus that allows to include in the analysis the characteristics of the social organization of the knowledge economy (Boyer, 2004; Petit, 1996; Vercellone, 2003; Coriat, Petit, Schmeder, 2006).

The Cognitive Capitalism approach enables to grasp the overlapping of knowledge and capital: knowledge becomes capital by means of the interface between knowledge generation as a specialized activity intertwined with the working of financial markets that play the indispensable role of mechanisms of knowledge exploitation and valorization (Petit, 1996; Boyer and Schmeder, 1990; Jin and Stough, 1998).

The "Varieties of Capitalism" approach stresses the role of the institutional coherence of socio-economic systems in accounting for their economic performances (Hall and Soskice, 2001; Amable, 2003). Different types of capitalism can be identified according to their coordination mechanisms. Two coordination mechanisms are identified: market-coordination mechanisms and institutional mechanisms. Four main economic spheres are investigated: i) industrial relations; ii) vocational training an education; iii) corporate governance; iv) inter-firms relations along value chains.

Industrial relations play a central role in the analysis. They include the variety of bargaining relations over wages and working conditions, the definition of incentives and the participation of workers to the definition of the procedures and goals of the firms. Two alternative types of capitalism are identified: i) the coordinated market economies and ii) the liberal market economies. The former rely more on institutional coordination mechanisms, the latter use the market place as the primary mechanism to coordinate the system.

Hall and Gingerich (2004) and Kenworthy (2005:73) have elaborated a measure of the levels of institutional coherence based upon the following indicators that focus on corporate governance and industrial relations:
(a) share of corporations based upon the separation between management and control, measured by the role managers coupled with dispersed shareholders with respect to dominant shareholders;
(b) relative size of the stock market, measured by the ratio of the value of public corporations on gross domestic product of a country;
(c) wage coordination, measured by the level at which unions normally coordinate wage claims and the degree to which wage bargaining is (strategically) coordinated by unions;
(d) labor turnover, measured by the share of employees who had held their jobs for less than one year.

The levels of institutional coherence of a system are determined by the levels institutional complementarity: "two institutions can be said to be complementary if the presence (or efficiency) of one increases the returns from (or efficiency of) the other" (Hall and Soskice, 2001:17).

The "Varieties of Capitalism" approach contends that the levels of performances of an economic system is a function of its institutional coherence: "When firms coordinate successfully, their performances will be better, and the result will be better overall economic performances" (Hall and Soskice, 2001: 45).

The institutional coherence of a system influences its performances not only in terms of levels and quality of the coordination procedures that reduce risks, uncertainty, transaction costs, but also in terms of innovative capabilities.

Coordinated market economies are better able to generate and exploit incremental technological changes while liberal market economies are better able to generate and exploit radical innovations. Corporations managed by controlling shareholders that rely on skilled workers and managerial regimes that provide enough worker autonomy and secure employment can take advantage of learning processes at the shop floor and capitalize on the tacit knowledge accumulated and introduce incremental innovations. Corporations with dispersed shareholders active in labor markets with high rates of turnover coupled with extensive equity markets are not only better able to hire talents with high levels of human capital, but also to take advantage of the flows of new high-tech firms generated by venture capitalism, acquire by means of take-overs in equity markets and introduce radical innovations. It is worth noting that also the Varieties of capitalism approach falls short exploring and assessing the systemic determinants of the direction of technological change.

4.2 SCHUMPETERIAN GROWTH REGIMES AT WORK

The grafting of the advances of the economics of knowledge upon the Schumpeterian legacy enables to explore how the changing mechanisms of the governance of knowledge generation, appropriation, accumulation and exploitation have direct effect on the aggregate dynamics of the system.

Three growth regimes can be identified: the entrepreneurial growth regime; ii) the corporate growth regime; iii) the knowledge growth regime. Table 4.1 summarizes the key characteristics of knowledge generation, appropriation, accumulation and exploitation and the mechanisms of knowledge governance. Table 4.2 summarizes the characteristics of the meso and macro system dynamics that parallel the different mechanism of knowledge governance.

INSERT TABLE 4.1 ABOUT HERE

INSERT TABLE 4.2 ABOUT HERE

4.3 THE ENTRPRENEURIAL GROWTH REGIME

The Schumpeterian *The theory of economic development* provides the basic tools to identify the entrepreneurial growth regime implemented in Europe for more than hundred years since the end of the 18th century. The recombinant generation of new knowledge is the outcome of a bottom-up process of accumulation of competence and tacit knowledge that relies on learning by doing and learning by using. Tacit knowledge based upon learning processes is implemented by the contribution of the scientific community that helps its codification and generalization. The bottom up generation of new knowledge relies heavily on the access to the stock of quasi-public knowledge made possible by vertical -between users and producers- and horizontal -between competitors- proximity within industrial districts. The mobility of skilled craftsmen across firms is very high and increases the spread of knowledge within industrial districts.

In the entrepreneurial growth regime the academic system plays an important role as it supports the codification and generalization of the tacit knowledge accumulated by means of learning processes within small firms that are not able to command the generation of technological knowledge with internal research activities. Scientists are involved in the generation of technological knowledge as "consultants" that provide their professional services. Academic institutions do not participate to the process but allow their members to supply their personal and individual services to small firms.

In the entrepreneurial growth regime there is a continuous flow of entry of new entrepreneurs. The life cycle of firms is short. Like the Marshallian forest trees, the survival of firms is short and the decline and exit of firms is rapid. Entrepreneurs acquire their competence on-the-job and are often formers employees of incumbents. The short life cycle of firms reduces the accumulation of the stock of knowledge within firms. Technological knowledge is primarily a collective good and its accumulation takes place primarily within the web of interactions that take place in industrial districts that are the depositary of technological knowledge. Industrial relations are characterized by the central role of highly skilled manpower with distinctive craft competences that retains the full control of their competences and are actively involved in the accumulation of tacit knowledge ant its eventual exploitation. The innovation process rests heavily upon the accumulation of tacit knowledge and competence and is directed primarily upstream towards the introduction of new capital and intermediary goods that make longer the value chain and the roundaboutness of the aggregate production process increasing the levels of division of labor and specialization both within firms and especially at the system level. The rates of imitation and introduction of incremental innovation are fostered by the low levels of knowledge appropriability that is based upon the relevance of tacit knowledge. The dissemination of technological knowledge is possible only by means of personal interactions within industrial districts.

The Entrepreneurial Growth Regime exhibits the typical traits of a profit-led mechanism of accumulation: the introduction of innovations is driven by the high levels of transient profitability (Boyer, 1988a and b). Investments in upstream activities in turn are driven by the rates of introduction of innovations and support their diffusion. At the system level the accelerator dynamics contribute the increase of the aggregate demand. The direction of technological change is strongly capital intensive for two broad set of reasons: i) the introduction of capital intensive technological change is induced by the strong trend of increase of wages of workers more and more able to increase their bargaining power by means of trade-unions and works as a form of meta-substitution of labor; ii) the capital intensive direction of technological change is consistent and complementary with the introduction of process innovations that increase the levels of roundaboutness of the production process.

The small size of firms limits the opportunity to take advantage of knowledge extensibility: firms are not able to manage large scale production processes and cannot spread the application of a given unit of knowledge to large output flows.

The distribution of income is highly skewed. Successful entrepreneurs cash the short lived extraprofits and the levels of retention are very low. Entrepreneurial families grasp a large part of national income and increase systematically their wealth: rent and wealth inequalities are very high. Wage inequalities are also high: skilled craftsmen employed in the manufacturing industry are far above the average in agriculture and traditional service activities.

The innovative banker is the primary source of the financial resources for new undertakings and plays a key role in the selection and support to the introduction of innovations. The innovative banker relies on a web of professional competences to sort the projects that are more likely to be successful and pay back the credits provided by the bank. The errors of exclusion are limited by the quality of the portfolio of professional competences that the innovative banker uses to sort the projects. The innovative banker suffers the intrinsic asymmetry: it cannot participate into the profits of successful ventures but is fully exposed to the negative effects of the failures in terms of non performing loans.

4.4 THE CORPORATE GROWTH REGIME

The 1942 contribution *Capitalism socialism and democracy* provides the basic tools to identify the corporate growth regime. The introduction of radical innovations in the organization of firms, the separation between ownership and control with the identification of professionalized managers and the consequent increase of the share of retained profits and the integration of the generation of technological knowledge within the corporation where specific activities, eventually named Research and Development, guided by corporate scientists dedicated to the intra-muros generation of technological knowledge and the introduction of innovations that enables the growth of firms are identified by Schumpter as the key characteristics of the "American capitalism" that gave the US the international leadership in innovation and economic growth since the early 20^{th} century (Chandler, 1962 and 1977).

The recombinant generation of knowledge funded by and performed within the corporation builds upon the control of the relevant internal stock of proprietary knowledge by means of systematic R&D activities. The access to and the absorption of the stock of quasi-public knowledge is relevant but to a lesser extent with respect to the Entrepreneurial Regime. Imitation from rivals engaged in oligopolistic competition in the same product markets is an important source of knowledge.

The role of the academic system is less relevant than in the entrepreneurial growth regime. The corporation internalizes the performance of applied research and development and participate directly into the generation of scientific knowledge. The academic system specializes in the generation of pure science at one extreme and training at the other extreme.

The corporate growth regime is characterized by large firms, ruled by managers, engaged in oligopolistic rivalry based upon systematic product differentiation of final goods in consumer markets. Industrial relations are characterized by mass production based upon assembly chains that engage workers with low levels of skills, competence add human capital, and participation to the accumulation of tacit knowledge. Within the corporation a core of highly skilled workers with managerial functions takes responsibility for the accumulation of knowledge, its recombinant generation and its exploitation for the introduction of innovations within the context of long term corporate strategies.

The direction of technological change in the corporate growth regime is basically neutral. This neutrality however is the result of two contrasting forces. The innovative process is mostly directed towards the introduction of product innovations that require higher levels of labor intensity. At the same time, however, the efforts to reap all the benefits of knowledge extensibility, push towards the introduction of mass production that requires high levels of capital intensity.

Corporate wages are well above short term productivity levels pushed by the strong bargaining power of highly unionized labor that enable workers to share the large markup of corporations (Farber, 2018). Corporate high wages, however, are efficiency wages as they enhance the participation of skilled workers to the accumulation of competence by means of learning processes that enable the generation of technological knowledge at costs below equilibrium and support the creative response (Stiglitz, 1974).

The dynamics of wages is strongly associated to the rates of introduction of innovations and increase of productivity levels, not only by means of the accumulation of tacit knowledge but also via the aggregate dynamics: the demand pull comes into play. The increasing level of wages supports the aggregate demand that in turn pulls the introduction of further product and process innovations and their diffusion embodied in the new vintages of capital goods brought into the system by the accelerator dynamics of investment. The high wage strategy supports the multiplier-accelerator dynamics within the loop aggregate demand-investment-demand-pulled innovations that feeds the introduction of further innovations.

The wage-productivity nexus has positive effects not only on the persistence of the rates of growth of output and productivity, but also on income distribution. Rent inequality declines from the high levels that characterized the Entrepreneurial Regime.

The levels of knowledge appropriability are far stronger than in the Entrepreneurial Growth Regime as they are augmented not only by more stringent IPR regime but also and primarily by substantial barriers to entry and mobility -based upon cost advantages stemming from the extensibility of knowledge, prime-mover advantages and economies of scale and scope- that reduce the risk of imitative entry. Incumbents are able to stretch the duration of transient monopolistic rent stemming from the introduction of innovation. The extended duration of the exclusive command of technological knowledge favors the internal accumulation of technological knowledge and its systematic use to feed the persistent introduction of additional innovations. The separation between ownership and control enables managers to retain large share of extraprofits and use them to fund internally the innovation process.

Competent teams of managers elaborate long term planning devices to focus the internal generation of knowledge, to sort the array of possible innovations generated by internal R&D laboratories and to implement consistent innovative strategies. The errors of inclusion of bad projects are reduced by the quality of the internal teams highly competent in their fields of expertise and practice.

For this very same reason, however, the corporate growth regime suffers dramatically the errors of exclusion. Internal selection procedures are unable to identify radical innovations that impinge upon technological knowledge(s) that are far away from the current core competence of the managerial teams.

Huge coordination costs limit the viability of corporations that are forced to implement new specialization strategies based upon the systematic use of outsourcing that includes knowledge generation activities. Corporations purchase knowledge, generated by small firms, both as a service and the equity of high-tech startups acquired in financial markets.

At the system level, the twin globalization of product and financial markets undermined the viability and economic sustainability of the corporate growth regime. The competition in global product markets of the output manufactured in low wage countries often by global corporations could not be resisted by the manufacturing industry of advanced countries. At the same time the globalization of financial markets favored the reduction of the levels of international spread and the access of industrializing countries to credit provided by global financial institutions. The creative response of advanced countries could not be based upon the introduction of biased technological change directed to increased levels of output elasticity of fixed capital: the difference in the cost of capital was not sufficient to secure a profitable division of labor.

4.5 THE KNOWLEDGE GROWTH REGIME

The knowledge growth regime is substituting the corporate growth regime. The knowledge growth regime is characterized by the vertical disintegration of the generation and exploitation of knowledge that leaves the corporation and becomes the core activity of a specialized knowledge industry.

Advanced countries have specialized in the upstream and downstream rings of the value chains, focusing on: i) upstream in the generation of technological know-how necessary for the design and engineering of products and processes, ii) financing the generation of knowledge as well as the production cycle, and iii) downstream in the process of enhancing tangible goods - physically produced in industrialized countries - controlling the wide range of activities ranging from logistics, distribution, marketing, and advertising that can be defined as commercial knowledge.

The organization of the production process is fully redesigned: advanced countries retain the knowledge-intensive phases both upstream and downstream the manufacturing process. Upstream activities such as the generation of new knowledge, its transformation into prototypes and advanced production, as well as downstream ones and the financial process take place in advanced countries. The manufacturing process itself is redesigned with the identification of knowledge-poor activities that are assigned to plants located in industrial countries and knowledge-intensive ones with higher requirements in terms of skills and larger opportunities in terms of learning processes are kept in knowledge abundant countries.

The decomposition of value chains in the global economy and the redefinition of the international division of labor see emerging countries take on the role of industrial economies specializing in manufacturing products and advanced countries the role of producers of inputs of knowledge, not only technological but also organizational and commercial, in the form of intermediate goods and especially intangible capital assets and KIBS.

The emergence of the knowledge industry parallels the demise of the corporation as the locus of generation and exploitation of knowledge and the shift of the locus of appropriation of knowledge rents. The vertical disintegration of the knowledge generation activities –traditionally performed by the corporation - and the stretching of the chain value parallels the shifts of the locus of exploitation and valorization of knowledge as an asset.

Firms specializing in knowledge generation activities exploit their output with two mechanisms: i) they sell directly knowledge as a service in the quasi-markets for knowledge; and ii) transform knowledge into knowledge-intensive equity that can be sold in financial markets with venture capitalism. The valorization of knowledge capital shifts upstream. The change is quite radical. Downstream corporations acquire knowledge assets that incorporate already a large chunk of the knowledge value that used to be valorized in product markets.

The large literature that explores the digital economy after the introduction of ICT complements the advances of the economics of knowledge as it has enabled to grasp the radical changes in the generation and use of knowledge. Digital technologies, in fact, provide the basic infrastructure that enables to collect, retrieve, store the knowledge items dispersed in the system and manage the recombination process. In so doing the array of digital technologies becomes the basic infrastructure of the knowledge economy. ICT are the technological basis of the knowledge growth regime as much as the assembly line was the basis of the corporate growth regime and the steam engine was the basis of the entrepreneurial growth regime: ICT enable the industrialization of the generation of knowledge (Frøslev Jens, Maskell, 2003; Johansson, Karlsson, Stough, 2006; Greenstein, Goldfarb, Tucker, 2013; Goldfarb, Greenstein, Tucker, 2015).

Knowledge externalities play a central role in the new mechanisms of (digital) recombinant generation of knowledge in terms of both the size and the variety of the stock of knowledge available in the system.

The recombinant generation of scientific knowledge is now twisted towards top-down processes. Scientific, highly codified, knowledge precedes its eventual application. The borders between scientific and technological knowledge are radically blurred. The recombinant generation of knowledge is now centered on the academic system. Universities contribute the generation of knowledge with three distinct mechanisms: i) they provide the system with a large supply of knowledge externalities triggered by the augmented amount of scientific publications and improved dissemination; ii) they are active in the new markets for knowledge where they supply scientific knowledge to corporations that outsource the performance of research activities; iii) they are the source of scientific entrepreneurship where former scientists engage directly in the -tentative- exploitation of the new scientific knowledge.

The generation of knowledge consists in the systematic interaction between generic and specific knowledge. General laws are applied to specific contexts and yield both innovative solutions and clues to implementing new general laws. The speed of the interaction and the variety of applications are the primary source of appropriation.

The new organization of the generation of knowledge parallels significant changes in its exploitation and valorization. The effects of the limited appropriability and exhaustibility of knowledge are most relevant not only in its generation, but also in its exploitation and valorization as they engender radical information asymmetries between vendors and customers.

Venture capitalism supports the embodiment of new knowledge in new firms assisting their birth and selective growth through the process that leads to their eventual entry in the stock markets and the final acquisition by corporations. Financial markets enable the systematic exploration of the knowledge landscape embodied by new firms based upon scientific entrepreneurship and become the new mechanism to coordinate the generation and the exploitation of knowledge as a financial asset.

Knowledge intensive business services are able to trade knowledge as a service. The stock of proprietary knowledge is the principal input. Its application enables providers to satisfy the specific and highly idiosyncratic needs of customers. Intensive learning processes, articulated in learning-by-doing, learning-by-using and learning by-interacting within user-producer relations enable knowledge producers at the same time to provide customers with useful inputs and to implement their stock of proprietary knowledge and to access relevant knowledge externalities.

In this context, scientific entrepreneurship is an indispensable mechanism for the effective use of the opportunities provided by the limited appropriability of scientific knowledge generated by scientific institutions. Scientific entrepreneurship is a distinctive and effective mechanism for the generation of new technological knowledge by means of the recombination of scientific knowledge spilling from academic institutions and the necessary variety of other knowledges and knowledge sources including commercial and technological knowledge. Spillover entrepreneurship has been able to guide the creative destruction that has characterized the shake-up of traditional corporate sectors like hardware electronics and big-pharma with the introduction of digital and bio technologies that were far away from the core competence of incumbent corporations.

The knowledge spillover theory of entrepreneurship identifies the new channel by means of which knowledge spillover are actually used. So far, the literature had focused primarily the knowledge interactions that take place among incumbents, paying little attention to the role of new comers as users of knowledge spillovers both to introduce innovations and to generate new technological knowledge. The large literature based upon the knowledge spillover theory of entrepreneurship explores systematically how and why knowledge spillovers provide the opportunity to entrepreneurs to create a new firm (Audretsch and Keilback, 2017 and 2008; Audretsch and Link, 2019).

Scientific entrepreneurs try and apply the results of basic scientific research achieved in academic and public research centers with the creation of start-ups. Industrial relations within start-ups are based on high levels of turnover and direct participation of selected and highly skilled personnel to the generation of new knowledge and its transformation into prototypes.

Employees participate directly not only to the generation of knowledge but also to its exploitation: their income includes stock options that associate directly the amount of wealth –as distinct from income- distributed to workers to the actual levels of capitalization of the knowledge assets that have been produced and exploited by means of knowledge and financial markets. The governance of startups is shaped by the increasing levels of separation between the original ownership of scientific entrepreneurs and the increasing role of competent managers seconded by venture capital firms.

The working of the "quasi-markets" for knowledge as a service and a financial asset shares the intrinsic characteristics of monopolistic competition. Each bit of knowledge is a unique product that commands quasi-rents. The exploitation and valorization of knowledge take place in a context characterized by a web of knowledge interactions and transactions where the price is contextual.

In the knowledge growth regime, the exploitation of knowledge directly produces wealth, without taking the form of income. The traditional laws of income distribution do not apply to the wealth created and its distribution to the production factors does not follow any clear (economic) rule.

The central relationship between the rates of increase of labor productivity and the rates of growth of output centered upon the manufacturing industry that shaped the Fordist age, is now questioned (Boyer, 2004). The distribution of the wealth and income stemming from the generation and exploitation of knowledge exhibits a significant shift. A large part of the wealth is retained upstream by the producers of knowledge and the financial system that make its exploitation possible. The knowledge and the financial industry are characterized by high wages and income levels augmented by the direct participation to the stream of wealth by means of stock options. The share of appropriation of the stream of income generated by knowledge concentrates upstream. Downstream customers appropriate declining shares and consequently squeeze the remuneration of production factors and especially labor engaged in downstream activities.

The new specialization in the generation and exploitation of knowledge triggers the segmentation of the labor markets in two sections: the market for creative labor and the market for standard labor. The levels of wages and employment of standard labor are fully exposed to the dynamics of factor costs equalization triggered by the globalization of product markets and exhibit a clear decline. The markets for creative labor, on the opposite, are protected by international competition and on the demand side the knowledge intensive direction of technological change exerts powerful effects supporting wage levels. Increasing wage inequalities add to the wealth and rent inequalities triggered by the new mechanisms of knowledge exploitation based upon the capitalization of knowledge and contribute to increasing the levels of income inequality (Atkinson, 2015).

4.6 CONCLUSIONS

The Schumpeterian notion of growth regime becomes necessary to understand the structural transformation of advanced economies. The discontinuity experienced by advanced economies since the last decade of the XX century can be fruitfully analyzed as the consequence of the shift from a mode of organizing the generation, exploitation and accumulation of knowledge centered upon the industrial corporation to a new mode based upon a specialized knowledge industry.

Schumpeterian growth regimes define the alternative sets of systemic conditions at the microeconomic, mesoeconomic, macroeconomic and institutional levels that shape both the out-of-equilibrium conditions that stir the reaction of firms and the mechanisms of knowledge governance that support the generation, exploitation and accumulation of knowledge and the generation of the endogenous knowledge externalities upon which the creative reaction and the consequent introduction of innovation is contingent.

The shift from a Schumpeterian growth regime to another takes place when the mechanisms of knowledge generation and exploitation in place reveal their limits and are no longer compatible with the structure of the system and relevant organization innovations at the system level provide new opportunities. The entrepreneurial growth regime was limited by the contradictions of the credit system as the prime provider of finance for innovation and by the small size of firms that could not reap the benefits of the extensibility of knowledge in terms of its repeated use for large scale production. The corporate growth regime had been able to combine equity finance with the exploitation of knowledge cumulability and extensibility. The corporate growth regime failed because of its limits in funding radical technological breakthroughs. The new knowledge growth regime is based upon the combination of scientific entrepreneurship with equity finance organized by venture capitalism and financial markets that enable to exploit knowledge as a capital asset. The vertical disintegration between the generation of knowledge and its repeated use as an input into the production of other goods made possible the combination of the benefits of small size in its generation with the large size in its use. The limited access to the existing stock of technological change raised by the current IPR regime impedes the full exploitation of the benefits of the limited exhaustibility of knowledge. The capitalization of knowledge undermines the distribution of the income generated by the exploitation of knowledge.

TABLE 4.1. KNOWLEDGE GENERATION, EXPLOITATION AND TECHNOLOGICAL CHANGE IN SCHUMPETERIAN GROWTH REGIMES

	ENTREPRENEURIAL GROWTH REGIME	CORPORATE GROWTH REGIME	KNOWLEDGE GROWTH REGIME
KNOWLEDGE CUMULABILITY	HIGH WITHIN INDUSTRIAL DISTRICTS	HIGH WITHIN CORPORATE BORDERS	VERY HIGH AT THE SYSTEM LEVEL
KNOWLEDGE EXTENSIBILITY	LOW	HIGH	HIGH
KNOWLEDGE APPROPRIABILITY	LOW, BASED UPON TACIT KNOWLEDGE	MEDIUM, BASED UPON BARRIERS TO ENTRY&IMITATION	HIGH, BASED UPON IPR
SOURCES OF INTERNAL KNOWLEDGE	LEARNING BY DOING, BY USING AND BY INTERACTING	INTERNAL R&D AND INTERNAL STOCKS OF	COMMAND OF SCIENTIFIC KNOWLEDGE

		PROPRIETARY KNOWLEDGE	
STOCK OF QUASI-PUBLIC KNOWLEDGE	MOST RELEVANT AS A SOURCE OF IMITATION EXTERNALITIES WITHIN MARSHALLIAN DISTRICTS	SPILLOVERS FROM COMPETITORS IN PRODUCT MARKETS: IMITATION EXTERNALITIES	SCIENTIFIC SPILLOVER WITHIN CLUSTERS AND KNOWLEDGRE STOCKS AT THE SYTEM LEVEL
KNOWLEDGE GENERATION	BOTTOM UP BASED UPON TACIT KNOWLEDGE	TOP DOWN BASED UPIN CODIFIED KNOWLEDGE	SYSTEMATIC INTERACTION BETWEEN GENERIC AND SPECIFIC KNOWLEDGE
DIRECTION OF TECHNOLOGICAL CHANGE	STRONGLY LABOR SAVING AND CAPITAL INTENSIVE	NEUTRAL	KNOWLEDGE INTENSIVE: FIXED CAPITAL AND STANDARD LABOR SAVING
TYPES OF INNOVATION	PROCESS INNOVATIONS EMBODIED IN NEW CAPITAL GOODS	PRODUCT INNOVATIONS	PROCESS INNOVATIONS

TABLE 4.2 SYSTEM DYNAMICS IN SCHUMPETERIAN GROWTH REGIMES

	ENTREPRENEURIAL GROWTH REGIME	CORPORATE GROWTH REGIME	KNOWLEDGE GROWTH REGIME
TYPICAL JOB PROFILE	SKILLED CRAFTWORKERS WITH LOW TURNOVER	DE-SKILLED MASS WORKERS IN ASSEMBLY LINES	SCIENTIFIC MANPOWER WITH HIGH TURNOVER
LABOR MARKETS	DUALISTIC LABOR MARKETS WITH HIGH WAGES FOR SKILLED INDUSTRIAL WORKERS AND LOW WAGE FOR THE REST OF WORKERS	FULL EMPLOYMENT IN HOMOGENEOUS LABOR MARKETS	MARKET SEGMENTATION WITH UNSKILLED WORKERS EXPOSED TO FACTOR COST EQUALIZATION AND KNOWLEDGE WORKERS WITH HIGH EMPLOYMENT AND INCOME
SIZE OF FIRMS	SMALL	LARGE	SMALL
SOURCE OF FINANCE	DEBT CAPITAL PROVIDED BY BANKS	RETAINED EXTRA-PROFITS	VENTURE CAPITALISM
TYPES OF COMPETITION	MARSHALLIAN COMPETITION IN INTERMEDIARY AND CAPITAL GOOD MARKETS	OLIGOPOLISTIC RIVALRY IN PRODUCT MARKETS	MONOPOLISTIC COMPETITION IN KNOWLEDGE MARKETS
KNOWLEDGE EXPLOITATION	AS AN INPUT FOR THE INTRODUCTION OF INNOVATIONS THAT COMMAND SHORT-LIVED EXTRAPROFITS	LONG LASTING MARK-UPS BASED UPON KNOWLEDGE EXTENSIBILITY AND CUMULABILITY	CAPITALIZATION OF KNOWLEDGE AS A FINANCIAL ASSET
INCOME DISTRIBUTION	HIGH WAGE AND RENT INEQUALITIES WITH LOW AVERAGE WAGES AND HIGH PROFITS	HIGH EFFICIENCY WAGES IN CORPORATIONS AND HIGH LEVELS OF RETAINED PROFITS	HIGH LEVELS OF WAGE AND RENT INEQUALITIES TRIGGERED BY KNOWLEDGE CAPITALIZATION
ENGINES OF GROWTH	PROFIT LED INVESTMENT EMBODYING TECHNOLOGICAL CHANGE IN INTERMEDIARY AND CAPITAL GOODS	HIGH WAGES DEMAND LED INVESTMENT IN FINAL PRODUCT MAKETS	INTANGIBLE INVESTMENT IN GLOBAL FINANCIAL MARKETS

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5. THE POLITICAL ECONOMY OF THE KNOWLEDGE GROWTH REGIME

ABSTRACT. The mechanisms of generation and exploitation of the new knowledge growth regime have major implications on income distribution and are likely to trigger a substantial segmentation of labor markets into the markets for skilled and creative labor and the markets for standard labor. In the context of the globalization of product markets factor costs equalization drives the wages of standard labor towards global averages that are lower than the pre-globalization levels. The knowledge intensive direction of technological change favors the resilience of the wages of creative workers. In the corporate growth regime, unions were able favor the internal distribution of the large oligopolistic gross margins increasing wages well above the levels of marginal productivity. The taxation of wealth and high income further reduced the income asymmetries. The small size of knowledge intensive business firms reduces the role of unions. The capitalization of knowledge helps increasing the levels of rent and wealth inequalities. The middle class is exposed to the twin pressure of the globalization of product markets, the dynamics of factor cost equalization and the knowledge intensive direction of technological and structural change. The identification of relevant dynamic increasing returns triggered by the limited exhaustibility of knowledge together with the need to contrast the increasing income inequality call for the effort to increase the social inclusion in the generation and exploitation of knowledge.

KEY WORDS: INCOME DISTRIBUTION; ROLE OF WAGES; LEARNING PROCESSES; KNOWLEDGE EXPLOITATION; MIDDLE CLASS; SOCIALIZATION OF KNOWLEDGE.

5.1. INTRODUCTION

The consolidation of the knowledge growth regime and the radical transformation of the economic structures of advanced economies calls for a political economy approach able to stretch the scope of investigation of the economics of knowledge to enquire about the new emerging social organization of advanced economies and to investigate the economic and functional role of the middle class.

Like, at the dawn of Fordism, the creation of the middle class was necessary to support the viability and sustainability of mass production, today it is indispensable to rebuild the foundations of middle class and to limit the exclusivity of IPR to overcome the intrinsic fragility of the knowledge growth regime.

The knowledge growth regime has now completed its run-off phase and can be fully considered the distinctive feature of the new economic and social system of advanced countries. The generation and use of knowledge, as an intangible economic asset, is now the main activity of the advanced economic systems and is the main source of income and wealth as well as the core for their specialization in the new international labor division. The generation, use and exploitation of knowledge are at the center of productive activity and concern the very nature of capital and its processes of accumulation.

For a long time, final consumers have been targeting increasing shares of their income for the purchase of high-quality services, while resources for durable consumer goods have long stagnated and, in relative terms, experienced a noticeable contraction (Bell, 1973). The turning point lies in the new centrality of knowledge as a service and both a capital input and a capitalized output on the supply side.

This chapter elaborates the hypothesis that the middle class - a new middle class- is strictly necessary for the stability of advanced economic systems. The middle class performs a crucial role of institutional mechanism that enables to overcome the limits and brittleness of the capitalistic production process. The changes in the capitalistic production process with the shift from the corporate to the knowledge to growth regime redefine the role and economic functions of the middle class. The middle class provided the corporate growth regime with an indispensable and complementary tool to implement and support the Keynesian aggregate demand. The transition from the corporate to the knowledge growth regime undermines the functional role of the middle class. Yet the consolidation of the knowledge growth regime seems possible only if a new middle class is organized with a new specific functional role.

The rest of the chapter shows how and why the middle class emerged as a radical institutional innovation at the dawn of the corporate growth regime and enabled its consolidation; explores the limits of the knowledge growth regime and shows how and why a new re-founded middle class is necessary for its consolidation and viability. The conclusions summarize briefly the main results.

It is time to set aside the many interpretations they have seen in the deep that marked the transition from the corporate to the knowledge growth regime by announcing an irreversible crisis of capitalism (Mazzucato and Jacobs, 2016), or the beginning of a secular stagnation (Gordon, 2016; Summers, 2014). These interpretations can be found in the tradition of the traditional neoclassical economic theory, which has no tools to analyze the processes of transformation out of the equilibrium that characterize the economy.

It is surprising, however, the consensus that these interpretations gather in those who fall outside the neoclassical field. Capitalism is based on continuous processes of crisis, transformation, recovery and growth. Capitalism cannot be in equilibrium: equilibrium is the true end of capitalism (Antonelli, 2017a and 2018c).

The dynamics of capitalism are marked by phases - as they happen with quite irregular and more or less prolonged rhythms- of crisis, transformation and recovery (Schumpeter, 1939).

It is necessary to reconsider, not only from the point of view of economics, but also and above all from the point of view of the political economy, the structure that the knowledge economy system is undertaking. The process of decomposing and redefining wealth production and income distribution is in fact so profound and radical to question not only the foundations of economics, but also the social structure of advanced countries and the role of the middle class.

The implications from the viewpoint of the political economy are powerful as they recall the causes and the processes that shaped the emergence of the middle class in the turbulent phase of the transition to the corporate growth regime and its functional role in the eventual consolidation of the corporate growth regime itself.

This chapter elaborates the hypothesis that the middle class is relevant not only from a sociological and political viewpoint, but also from an economic viewpoint (López and Weinstein, 2012).

The middle class performed –at the time of the corporate growth regime and can perform again within the knowledge growth regime- the indispensable role of social stabilizer of the intrinsic contradictions and brittleness of capitalism. The changing mode of capitalistic organization brought by the emergence of the knowledge economy calls for a new economic role of the middle class.

The middle class enables to enhance the positive effects of increasing returns beyond the limits of the marginalistic rules of income distribution. Within the corporate growth regime, the increase of blue collars' wages, beyond the marginal productivity of labor, was more than compensated by the rightward shift of the demand for the output of mass production. The cliometric evidence suggests that the right ward shift of the demand curve –determined by the increase of wages- did yield much a larger equilibrium point at the crossing with the average cost curve –characterized by the negative slope stemming from increasing returns- even after taking into account the upward shift of the cost curve stemming from the larger wages.

Within the knowledge growth regime, the cost of inclusion of marginal creative workers is more than compensated by the increasing returns, in terms of knowledge output, stemming from the recombination of a larger variety of knowledge items possessed by the augmented number of creative workers at work, and the higher chances to sort and include actual talents.

The emergence of the middle class at the dawn of the corporate growth regime can be regarded as a major institutional innovation that provided the corporate growth regime with the social foundations of the Keynesian aggregate demand implementing the dedicated support to the demand of the output of mass production. The parallel demise of the corporate growth regime and the decline of the middle class call for the analysis of the limits of the knowledge economy and its need of a new middle class.

A new middle class based upon different foundations and with a different functional role, is again, indispensable for the viability and sustainability of the knowledge economy.

5.2 THE MIDDLE CLASS AND THE CORPORATE GROWTH REGIME

The corporate growth regime, which lasted about 80 years since its introduction in the United States at the dawn of the twentieth century, to its long decline that coincided with the end of the same century, and had touched its apex in the "glorious thirty (years)" between 1945 and 1975, was based on the Fordist assembly line and the production on a large scale within the Chandlerian large firms (Chandler, 1964 and 1977).

The corporate growth regime had replaced highly skilled small-scale productions with standardized and standardized productions, and the skilled worker of manufacturing capitalism with the mass worker. Above all, it has placed at the center of the wealth creation and accumulation and income distribution, the corporation able to enhance and internalize significant increasing returns mainly related to the exploitation of economies of density and the accumulation of increasing stocks of knowledge. The corporation is the fulcrum of the corporate growth regime as much as the assembly line.

Workers in the assembly line mature an increasing awareness of their central role in the overall capacity of the system to produce income and wealth. White collars in the organization of corporations are the second economic and social leg of the corporate growth regime. Fordism provided the basis and the opportunities for the emergence of the middle class.

The middle class was the main result of a trade union and political action that has been able to enhance the basic conditions of the Fordism itself. The formation of a broad consumer group became the very basis for the expansion of Fordism and its economic benefits.

In the United States, the welding between blue and white collars took place mainly through and within the corporation where the union force was able to organize the birth of the middle class through a very strong increase in blue-collar wages to the level of the white collar. The business bargaining allowed trade unions to identify the emerging islands of Fordism and concentrate there a powerful work of enhancing wage salaries and targeted action to participate in the design of business organizations by promoting the integration of blue and white collars (Farber et al., 2018).

The middle class in the corporations managed to attract and absorb progressively professional and commercial intermediaries and integrate public workers into a relatively homogeneous social block. In Europe, the same clotting action was mainly carried out by the state.

The welding between white collars and blue collars was based on the awareness that their alliance was the lintel, the supporting structure of the "general class" based on the centrality of the corporation in the production process. The corporation, based on the assembly line and the great organizational structures, was indisputably the privileged site of creation of income. As such, it dictated the models and procedures of social and political action that gradually spread in the whole social system of the great Atlantic democracies.

The establishment of the middle class was not obvious. The birth of the corporate growth regime had not been painless. The advent of mass production has been itself a process of creative destruction that reshaped industrial capitalism with the substitution of the corporation to the fabric of small, highly specialized businesses, deprived skilled workers of their craftsmanship and the collapse of the family-led entrepreneurial ventures into which capital and skills were blended.

The corporate growth regime itself mingled in Continental Europe with forms of social and political organization far from democratic values . Consensus towards the totalitarian regimes came not only from the "agrarians", but also and perhaps above all from the reactionary drives of the social groups marginalized by the corporate growth regime itself.

The constitution of the middle class corresponded to the precise and intrinsic economic needs of the corporate growth regime. The strength of the corporate growth regime was based on its ability to organize and exploit the increasing returns that came from economies of scale and especially from the exploitation of knowledge extensibility and hence from the production of large amounts of relatively homogeneous durable goods based upon the very same technological blue prints. A strong and growing final demand was obviously indispensable for the economic sustainability of the corporate growth regime.

Middle class is based on a distribution of income that favors the convergence between median and average wages and allows to fuel a strong and growing demand for durable consumer goods. The strong increase of wages in corporations was the economic foundation of both the middle class and the corporate growth regime. As a matter of fact, the strong increase of wages was made possible by the strong bargaining power of trade-unions in large firms that made possible to sharing the rents stemming from the increasing returns enjoyed by corporations (Farber et al., 2018).

Within the corporate growth regime, the increase of blue collars' wages beyond the marginal productivity of labor was able to increase the overall revenue levels at the system level and the profitability of corporations because of the working of increasing returns in mass production. The increase of wages did push to the right the demand curve so as to yield much a larger equilibrium. Increasing returns gave the average cost curve a strong negative slope able to compensate for the upward shift stemming from the larger wages. The corporate growth regime had become wage-led after the negative outcome of the attempt elaborated in the thirties to combine a profit-led growth with mass production (Boyer, 1988a and b).

With the advent of the knowledge growth regime the functional fundamentals of the middle class in the corporate growth regime have progressively declined. The support of the demand provided by the high wages paid to assembly line workers -once indispensable to increase the aggregate demand- now risks to benefit –only- the import of the output of a manufacturing industry fully delocalized in low-wages countries. The formation of the knowledge growth regime questions not only the economic bases of the middle class, but also its functionality.

5.3 THE DEMISE OF THE CORPORATE GROWTH REGIME AND THE DECLINE OF THE MIDDLE CLASS

Replacing the knowledge economy to the manufacturing economy is an aspect of a deeper structural transformation of the economy that affects the whole organization of the economic system, as much as the advent of the corporate growth regime itself. In the first decades of the 20th century, the consolidation of the corporate growth regime was accomplished through the destruction of a whole production mode and its social articulations, undermining the foundations of the manufacturing bourgeoisie and skilled workers with knowledge and crafts and hence in fact privileged. Today the gradual consolidation of the knowledge economy is accomplished through the decline of manufacturing industry and the expulsion from the production processes of the unskilled workers -the mass workers- who had formed the core of unionized blue collars. The mass worker who expelled the craftsmen is now marginalized by the creative workers who are the basis of the knowledge economy.

As then the corporation assumed the role of pulling the economic system through the generalization and expansion of large-scale production to every possible field, today the production and exploitation of knowledge as capital is the driving force. The academic-financial complex has become the new pivot. The transition is overwhelming as it is accelerated by a globalization that acts on multiple fronts by breaking ties and connections that seemed inextricable.

Aggregate demand is now global as well as the organization of value chains. The increase in middle-class consumption capacity, a time indispensable to Fordism, is now superfluous by the real possibility of collecting pay-demand segments on global scale. Only companies capable of acting on global markets can survive. Domestic demand subsidies and in general all the efforts to support the domestic aggregate demand only strengthen the impetus of imports from industrialized countries.

The high wages paid to assembly line workers in the corporate growth regime were compatible with the large rents earned by corporations within national markets protected by international competition on two counts: i) competition among firms that shared the high wage strategy was symmetric; ii) aggregate demand was not exposed to competition from low wage countries.

Equally obvious is the breakup of the connections between knowledge generation and the production of goods. What happened within the strong vertical integration of corporations, today it is done through the valorization and exploitation of knowledge directly on the financial markets of companies capable of generating knowledge and as such acquired at high prices by global corporations. The corporation was at the same time the center of the mass production and an extraordinary internal market in which it crossed its ability to generate knowledge with its financial capabilities sustained by extra profits gained on the oligopolistic markets of the final goods. The task of the corporation was not only the manage the economies of scale, but also, and perhaps above all, the generation of knowledge that would allow to renew the increasing returns over time through the introduction of product innovations.

The formation of the knowledge growth regime takes place in a context of crisis and transformation very similar to the turn of the corporate growth regime also with respect to the working of financial markets. Even the euphoria of the financial markets faced with the new way of producing immense profits that emerged, and the subsequent dramatic crises, due to speculative excesses, which had however made available to the rising corporate growth regime the massive resources needed to create the bases of mass production, took on some of the features found in many of the early financial events of the XXI century.

The 2001 dot.com bubble is the real cause of the 2007 crisis, also due to the mistakes of an overly accommodating monetary policy, to handle the 2001 crisis, that indeed fueled the real estate prices and then, with a sudden change, overly restrictive. The dot.com bubble, however, made available to the new knowledge capitalism an extraordinary amount of resources that enabled it to create its digital technology bases. Even the incredible mistakes of economic policy of the Coolidge and Hoover presidencies recall the disasters, this time European, of the fiscal compact.

Vertical disintegration of knowledge generation and exploitation is accomplished both through globalization, which strengthens the international division of labor, and through the financial markets in which capitalizing on the ability to produce knowledge.

Radical innovations in the organization of the knowledge generation processes, increasingly external to corporations, put the interaction between knowledge and finance at the center stage. Knowledge, no longer embedded in tangible goods, can only be valued because it is transformed through financial markets directly into financial capital. The true measure of the value of knowledge is by now the Tobin’s q (Antonelli and Colombelli, 2011a).

The formation of a new academic-financial complex emerges at the core of the system. Knowledge production abandons the large R&D department of corporations and is more and more placed in the academic sphere. The traditional distinctions between science and technology, as well as the three-part OECD-based trials, from basic research, to applied research and development research lose their empirical foundation. Science and technology are an integral and indissoluble field in which the academic ethos fully unfolds its liberal origin. The academy produces knowledge.

Venture capital performs the critical role of screening mechanism that tests the actual economic use of the new knowledge and nurtures its selective application to economic activities. Finance deals with its exploitation.

Knowledge exploitation moves upstream in the value chains and is inextricably intertwined with finance. Since it is almost impossible to buy and sell knowledge as such, knowledge exploitation takes place primarily through the sale and purchase of *knowledge-intensive-equity,* or transactions in the ownership of companies and business units that incorporate knowledge that has been proven source of profits (Antonelli and Teubal, 2008 and 2010).

The exploitation of knowledge as a capital asset produces enormous rents that are partially shared with the creative workers that originate it. Manufacturing corporations are deprived of much of the value of the knowledge they need to compete. The annuities have moved upstream. The mechanisms of knowledge generation and exploitation are in turn at the origin of a new social structure.

It is a grave mistake to believe that the knowledge economy is not building for its indispensable necessity a coherent and functional social structure. Indeed, the evolving character of a new social class is evident, of which knowledge makers –the creative labor- and the managers of financial exploitation mechanisms –the financial community- are the two, complementary economic and social components.

Standard income distribution rules, based on the marginal productivity of production factors, cannot apply in the distribution of wealth generated by the exploitation of knowledge directly as a financial asset. The new financial wealth generated by the exploitation of knowledge is allocated to its two components, creative workers and finance workers, with ad hoc rules. The opacity of the mechanisms and allocation procedures that dictate the distribution of income in the knowledge economy is one of its main causes of its fragility and limited sustainability.

At the same time, an increasing share of the income generated in the system is concentrated in the academic-financial system. In advanced countries, the profits of manufacturing firms are diminishing, due to the purchase at high cost of upstream knowledge, while industrial wages fall due to the effect of factor costs equalization triggered by globalization and reinforced by immigration.

The growing inequality in income distribution finds its causes in the ongoing crisis and transformation process. The crisis contributes to strengthening inequality for short-term economic reasons: the sharp increase in unemployment caused by the decline in manufacturing industries is itself the primary cause of increased inequality. The strong labor market pressure caused by international labor mobility that augments the supply of low-skilled workers, increases the impetus towards inequality as it favors the shrinking wage levels of low-skilled jobs already exposed to manufacturing contraction (Autor et al. 2003; Autor, and Dorn, 2013).

Alongside these dynamics of economic activity, the structural dynamics of the knowledge growth regime through the strong increase of financial capital partly shared with the income of knowledge workers -and financial managers- play a decisive role in skewing the distribution of both income and wealth (Aghion, Caroli, Garcia-Penalosa, 1999; Franzini e Pianta, 2016).

The ongoing evolution threatens the very foundation of the social and political structure that has allowed over 70 years of democracy. The ongoing segmentation of knowledge workers on the one hand and productive workers on the other is the cause and the consequence of the profound structural change in progress.

The marginalization of the constituent ties of the corporate growth regime, the mass worker in charge of the assembly chains and white collars responsible for the operation of the giant corporate bureaucracies, triggers conservative dynamics that sometimes take reactionary characters.

Knowledge –creative- workers increasingly acquire specific characteristics that move them away from the traditional political and trade union representations of labor. At the same time, they grow into a growing awareness of their "general-class" role as they hold the bases of wealth and income production.

The knowledge creative worker has very specific socio-economic characteristics: s/he manages his own human capital with business and financial criteria of which s/he is increasingly aware. It is characterized by high levels of mobility across firms and in regional space. He calls for protection of his human capital rather than the contingent working relationship. It's for self-employment rather than employee. The identification and formation of a separate social class is underway with enormous social, cultural and political consequences. This social class now exemplifies a cultural, almost anthropological, appeal. Intermediate, commercial and professional, classes are attracted to it. Public white collars are exposed to strong centrifugal forces from the traditional middle class and strongly centripetal with respect to the new social class.

5.4 THE MIDDLE CLASS IN THE KNOWLEDGE GROWTH REGIME

This is the ground on which the new great social and political game of the XXI century is played. Large risks and bifurcations are outlined. The formation of the middle class was the result of far-sighted politics and trade union action, but not obvious. Alongside the positive result achieved in the Atlantic democracies, forms of oligarchic democracy were produced when not even the establishment of totalitarian regimes.

The corporation, especially in the United States and to a lesser extent in Europe and the Welfare State, especially in Europe and to a lesser extent in the United States was, in a historical perspective, the strategic factor of a profoundly innovative and far-sighted political action. Political action was able to focus the constitutive problem of the corporate growth regime, that is, the creation of a strong aggregate demand that would allow full exploitation of increasing returns and find an institutional solution based upon the middle class.

The segmentation of the middle class is the direct consequence of the globalization of product markets and the creative response that led to the emergence of the new knowledge growth regime. The labor markets have experienced a drastic segmentation engendered by: i) the powerful effects of the dynamics of factor costs equalization with the decline of wages for standard labor employed in the production of tangible goods exposed to the increasing competition brought about by low-wage and labor abundant industrializing economies, coupled with ii) the increase of the derived demand for creative labor, able to participate into the generation and exploitation of knowledge as a capital asset with the consequent sharp increase of their total income as composed by wages and knowledge rents, triggered by the knowledge intensive direction of technological change, itself the outcome of the creative response that has led to the emergence and consolidation of the new knowledge growth regime; iii) the new mechanisms of knowledge exploitation with the increasing participation of creative workers to the appropriation of both knowledge capital and knowledge add to the increase the levels of rent and wealth inequality . These new mechanisms of generation and exploitation of knowledge and its role in the specialization of advanced systems within the global economy, have direct negative effects on the coherence of the middle class and are at the origin of intense processes of increasing income inequality.

It is necessary to start the search for mechanisms of social inclusion capable of combining the demands of democracy with an economic policy action capable of removing the intrinsic limits of the knowledge growth regime drawing from the extraordinary capacity of Western democracies to combine in the formation of the middle class, at the dawn of the corporate growth regime, not only the quest for democracy but also the strengthening of the corporate growth regime itself.

In the new knowledge growth regime, the game of the middle class rebuilding is played in the ability to govern inclusive processes of generation and accumulation of knowledge. The potentiality of a public policy aimed at implementing and supporting the "general intellect" are important from the viewpoint of both the social and the economic effects. A public strategy based on institution-building and knowledge-building mechanisms that increase the bottom-up participation to the generation and the exploitation of knowledge can play the role of integrating mechanism of a new middle class based on the enlargement of processes of knowledge generation and accumulation. The new social class needs to strengthen its participation in knowledge exploitation by containing capitalist accumulation processes.

The knowledge growth regime needs the middle class as much as the corporate growth regime. But for very different reasons. The contradiction between knowledge generation and exploitation is a source of fragility and radical uncertainty at the system level. The financial bases of knowledge exploitation are a constraint and a limit that curbs the dynamics of the generation itself. The high levels of risk associated with knowledge production are badly combined with the inability of financial markets to manage uncertainty. The exclusivity of IPR curbs the dynamics of the recombination processes on which the generation of knowledge is based. The growing separation in global production chains reduces the intensity of vertical flows of tacit knowledge and increasingly distances the processes of accumulation of tacit knowledge from the processes of generating codified knowledge (Pagano and Rossi, 2009, Pagano, 2014).

It is therefore necessary to put in place a political action based on mechanisms that are capable not only of countering the strong tendencies in the formation of an oligarchic democracy, but also to remove the intrinsic limitations of the knowledge growth regimes.

The knowledge growth regime has elements of radical fragility stemming from: i) the brittle suture between the processes of knowledge generation and knowledge exploitation; ii) the lack of rules able to combine fairness and efficiency in the distribution of financial wealth produced, in the form of income; iii) the intrinsic limits of knowledge generation mechanisms based on the individualism of excellence.

The distribution of income deriving from knowledge capitalized as financial wealth must be driven by inclusion mechanisms that promote the expansion of the knowledge-based generation processes and cannot be limited to excellence often identified only ex-post.

Because the generation of knowledge is a collective activity that consists in the recombination of the variety of existing knowledge items distributed in a myriad of agents, knowledge output increases more than proportionately with the increase of the variety of active agents that participate purposely to knowledge generation. The integration of the top-down approach to knowledge generation with the bottom-up approach calls attention to the need to integrate the traditional hierarchical vision according to which new knowledge is generated exclusively by “stars” with the appreciation of crucial role of the bottom-up participation of a variety of agents with heterogeneous skills and experiences.

An expanded participation through the building of an extensive social base for knowledge generation goes hand in hand with the strengthening of public institutions capable of generating knowledge.

The increase of the variety of knowledge-generating mechanisms and the participation in its exploitation is indispensable, not only to foster integration and therefore to build a new middle class but also to increase the ability of systems to produce knowledge. High quality mass education combined with inclusive and non-frustrating social outcomes is the only chance of identifying new potential Nobel prizes needed to enhance the capability of a knowledge-based system. Appropriate and non-exclusive valorization of human capital formation pathways is in turn indispensable to engaging potential talents.

It is evident that abandoning to forms of precariousness with no perspectives generations of young scholars is not only iniquitous, but also and above all, inefficient and counterproductive, because it devalues incentives to the same formation of human capital and thus slows down and stifles the finding of talents. In parallel with the enhancement of the learning process based on the tacit knowledge of workers without a doctorate, but carriers of valuable skills, based on bottom-up learning processes, can not only promote the convergence of blue-collar workers in the new middle class, but also broaden the capability of the system at large to generate knowledge.

The knowledge growth regime needs a new middle class because only such a middle class can support not only the capability to generate knowledge but the sustainability and viability of the knowledge economy at large.

Within the knowledge economy, the cost of inclusion of marginal creative workers is more than compensated by the additional revenue stemming from the Jacobs increasing returns engendered by the limited exhaustibility of knowledge and the role of its variety in the recombinant generation of new knowledge. The inclusion of -seemingly- marginal creative workers augments more than proportionately knowledge output because it enables the recombination of a larger variety of knowledge items possessed by the augmented number of creative workers at work and increases the chances to include, in the knowledge generation process, actual talents with high risks to social exclusion.

For the same token it seems clear that the reduction of the exclusivity of IPR is necessary to increase the actual productivity of the knowledge generation process. The exclusivity of IPR risks to delay the generation of new knowledge as it reduces the opportunity for new recombinations.

5.5 CONCLUSIONS

Schumpeterian growth regimes are unstable and intrinsically fragile. Their sustainability requires an institutional context able to overcome its limitations. The middle class has performed the crucial role of functional stabilizer of the corporate growth regime. The middle class provided the corporate growth regime with the Keynesian support to the aggregate demand and enabled the growth of the demand for the output of mass production upon which the corporate growth regime based its own performances. The demise of the corporate growth regime has paralleled the decline of the middle class and the rise of substantial income and wealth inequalities that affect the social viability of advanced systems.

The analysis of the role of the middle class at the time of the corporate growth regime has shown that the removal of the limits of the marginalistic rules of income distribution with the increase of blue collars' wages beyond the levels of their marginal productivity enabled to enhance the positive effects of increasing returns in mass production.

The re-foundation of a new middle class based upon the extension of the knowledge generation process with the inclusion of wider sources of knowledge is today crucial to support the consolidation of the knowledge growth regime. The knowledge growth regime has intrinsic and yet elements of brittleness stemming from the shaky foundations of its mechanisms of income distributions, the limits of its individualistic mode of knowledge generation and the bottlenecks of its financial exploitation. The creation of a new middle class based upon the social valorization of the knowledge generation mechanisms is necessary to stabilize and actually empower the working of the knowledge growth regime.

The inclusion of marginal creative workers with their participation to an extended knowledge generation process can, again, empower the positive effects of increasing returns stemming from the limited exhaustibility of knowledge and its recombinant generation process. Within the knowledge economy the inclusion of a larger variety of agents in the knowledge generation process can increase the knowledge output more than proportionately because of the powerful effects of Jacobs knowledge externalities and the scope for the "discovery" of unexpected talents.

The reform of the current IPR regime with the differentiation of patents according to their use and the reduction of their exclusivity seems indispensable to overcome the tragedies of anticommons and their limits to the full exploitation of the potentialities of the knowledge growth regime.

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6. TOWARDS A NEW KNOWLEDGE POLICY

ABSTRACT. The identification of the increasing returns triggered by the limited exhaustibility of knowledge and of the central role of the interindustrial knowledge externalities triggered by the dissemination of knowledge across product markets calls for a new knowledge policy aimed at reducing the exclusivity of the intellectual property regime with the introduction of two layers patents according to the activity of perspective users and new public subsidies based on high levels of additionality.

KEYWORDS: KNOWLEDGE POLICY; KNOWLEDGE INCREASING RETURNS; USER SPECIFIC PATENTS; R&D SUBSIDIES; ADDITIONALITY REQUIREMENTS.

6.1 INTRODUCTION

The viability of the knowledge growth regime depends upon the access conditions to knowledge. The analysis of the crucial role of knowledge calls attention on the need for a new knowledge policy. Traditional research policies have been heavily influenced by the large consensus about the Arrovian knowledge market failure. The analysis of the negative economic consequences of the limits of knowledge as an economic good has been implemented for several decades and provided the base for an articulated set of research policies aimed at increasing the incentives to the generation of knowledge deemed to be insufficient.

The cornerstones of the research policy that stems from the hypothesis of a generalized knowledge market failure due to the limited appropriability of knowledge, are: i) the public support to the generation of knowledge by means of the supply of scientific and technological knowledge with the creation of a public infrastructure including academia and specialized public research centers; ii) the provision of public subsidies designed to reducing the costs of knowledge generating activities so as to balance the negative effects of the persistent limited appropriability of proprietary knowledge even after the protection provided by patents; iii) the public support to knowledge exploitation with the implementation of the IPR regime designed to increase the appropriability of knowledge.

The results of the analysis carried out by this book suggest that quite a radical change is necessary. Knowledge is an economic good with special characteristics that enable economic systems and firms to take advantage of the dynamic increasing returns that stem from its limited exhaustibility and hence its cumulability and extensibility. Technological knowledge can be used again and again with limited effects in terms of wear-and-tear. Technological knowledge is not only an indispensable input in the technology production function i.e. for the production of any other good, but also an essential input for the recombinant generation of new knowledge.

The identification of the new properties of knowledge as an economic good calls attention on the merits and strengths of knowledge as an economic good and its pivotal role as the engine of dynamic increasing returns and questions the Arrovian assumption about the limits and weaknesses of knowledge because of its limited appropriability and the consequent market failure in terms of knowledge undersupply stemming from the lack of appropriate levels of incentives to its generation and use.

The recent advances of the economics of knowledge and of the new growth theory, integrated by the Schumpeterian legacy, have shown that the generation and exploitation of knowledge are characterized by increasing returns that take place at the system level and trigger out-of-equilibrium conditions. The generation of knowledge is. The limited appropriability of knowledge yields the combination of quasi-equilibrium conditions at the firm level: spillovers limit the appropriation of the more than proportionate increase of output with respect to knowledge inputs. Spillovers in fact yield knowledge externalities that benefit third parties that can access and use knowledge as a quasi-public good at low cost. The limited exhaustibility of knowledge makes possible the repeated use of existing knowledge to generate new knowledge at costs that below equilibrium levels. The larger is the stock of quasi-public knowledge that firms can access to pursuit the recombinant generation of new knowledge and the larger both the knowledge output and the total output of all the other goods that use technological knowledge as an indispensable input.

The special properties of knowledge i.e. its limited appropriability and exhaustibility, trigger out-of-equilibrium conditions because knowledge externalities -with appropriate knowledge governance mechanisms- enable the secondary use of existing knowledge as an input in the generation of new knowledge and enable to increase the levels of total factor productivity at the system level that are larger the larger the gap between the equilibrium cost of knowledge and its actual costs (Antonelli, 2018a).

Let us analyze the wheels of the mechanism in detail. The larger is the knowledge output at each point in time and -because of its limited exhaustibility and appropriability- the larger is the stock of quasi-public knowledge at time t+1. The larger the size and the variety of the stock of quasi-public knowledge and the better the knowledge governance conditions in the system that reduce absorption costs and enable to effective access to it- the lower is the cost of accessing to and using the stock of quasi-public knowledge in the knowledge generation function at time t+1. The lower are the costs of the stock of knowledge – that enters the recombinant knowledge generation function as an indispensable input- and the lower is the cost of knowledge as an input in the technology production function of all the other goods. The lower is the cost of knowledge in the technology production function of all the other goods and the lower are their cost. The lower are the cost of output and the larger its quantity, and larger are the positive effects in terms of total factor productivity. The exploitation and generation of knowledge are the cause and the consequence of conditions that are far from equilibrium. This dynamics is further reinforced by the forces that shape the endogenous direction of technological change and the search for technological congruence. At each point in time the availability of a larger stock of knowledge that can be accessed at lower costs induces the introduction of biased technological change directed at increasing the output elasticity of knowledge and its intensity of use. The augmented levels of technological congruence provided by the better matching between the availability of the cheaper input knowledge and its increased output elasticity in the technology production function, have the multiple effects of: i) increasing the demand for knowledge, hence its eventual generation with additional expansion of the knowledge stock, ii) enhancing the levels of total factor productivity and iii) strengthening its appropriability in the global product markets as rivals localized in less knowledge abundant countries can imitate but bear larger operating costs (Antonelli, 2018a).

This dynamic process exhibits the evident characters of dynamic increasing returns that make clear the positive effects of the increase of the flows of R&D activities at each point in time well beyond the boundaries of any equilibrium conditions.

The positive effects of the additional flows of R&D activities are a direct consequence of the full range of special characteristics of knowledge as an economic good: its limited appropriability, that makes its access and use possible to all the agents in the system, together with its limited exhaustibility that makes the accumulation possible. The knowledge externalities stemming from non-exhaustible knowledge spillovers benefit all the system.

In this new out-of-equilibrium- context the goal of knowledge policies should be to increase of the flows and the stock of knowledge available in the system, rather than restoring the supposed equilibrium conditions of the markets for knowledge. The increase of R&D activities should become the prime goal of public subsidies rather than the compensation of the missing revenue of “inventors” expropriated by the limited appropriability of knowledge.

This new approach, that highlights the merits, as opposed to the limits, of knowledge as an economic good and builds upon the new understanding of knowledge generation as a recombinant process into which existing knowledge is a necessary and indispensable input, has strong implications in terms of knowledge policies.

In this context there are strong and evident reasons for the public support to the generation of technological knowledge so as to increase the size of the stock of knowledge with its positive consequences. For the same token the public support to the improving the quality of knowledge governance mechanism is expected to yield positive effects in terms of better conditions of accessing and using the existing stock of knowledge (Antonelli, 2019a and b).

The analysis of the consequences of the limited appropriability of knowledge must be framed into the new context that appreciates the potentialities of knowledge for dynamic increasing returns. IPR are necessary to secure the appropriation of the rent stemming from the generation of technological knowledge and its use for the introduction of innovations. A system deprived of IPR risks indeed to face the fall of the incentives, at the firm level, for the generation of knowledge even accounting for its long term positive effects. The differentiation of IPR according to the use of proprietary knowledge whether in the technology production function as an input into the introduction of technological innovations or in the knowledge generation function as an input in the generation of new knowledge seems to open the way to a knowledge policy based upon the Open Technology approach.

The reduction of the exclusivity of IPR with the introduction of non-exclusive patents with compulsory licensing based upon the liability rule seems especially appropriate when existing knowledge is used for the generation of new knowledge. Perspective users of the existing proprietary knowledge can access and use it, provided that the owner of the IPR is informed and receives a fair royalty.

In the new analytical framework, the actual increase of amount of R&D activities carried out by private firms and hence the actual increase of the flows of knowledge generated at each point in time becomes the goal of public R&D subsidies. The shift from a knowledge cost reducing to a knowledge output increasing mission calls attention upon the additionality issue. The support to the generation of knowledge based upon the strong additionality requirements and the support to the exploitation of new technological knowledge with differentiated exclusivity levels seem the appropriate tools to implement a new knowledge policy based upon the Open Technology approach. Let us analyze them in detail.

6.2 THE PUBLIC SUPPORT TO KNOWLEDGE GENERATION

Public subsidies are aimed at the reduction of R&D costs as a mean to compensate firms for the missing revenue due to the limited appropriability of knowledge. Subsidies are finalized to restore the equilibrium conditions of the markets for knowledge. The equilibrium conditions of the markets for knowledge are upset by the limited appropriability of knowledge that undermines the incentives to its supply. Public interventions aim at restoring the equilibrium conditions. The pursuit of the increase of the level of R&D activities is a secondary goal of public intervention and is expected to take place only within the boundaries of equilibrium conditions. Public subsidies are expected to trigger an increase of R&D expenditures up the equilibrium level. Not beyond it.

This section elaborates a new approach to the analysis of the foundations of public subsidies to R&D activities performed by firms. The increase of the flows of R&D activities and hence –because of the limited exhaustibility of knowledge- of the accumulation of the stock of quasi-public knowledge should be the aim of public subsidies to R&D activities, rather than their mere cost reduction. Building upon these bases this section advocates the introduction of strong additionality requirements for granting public subsidies to R&D activities performed by private firms. Public subsidies should be granted only to firms that are committed to increase their R&D activities by an amount that is at least equal to the amount of the public subsidy.

R&D SUBSIDIES AND R&D ACTIVITIES

In the standard Arrovian framework, public R&D subsidies deemed necessary to compensate firms for the missing revenue of the innovations engendered by the limited appropriability of knowledge. Public R&D subsidies were finalized to compensate the reduced revenue with a reduced cost. The reduction of R&D cost was the basic aim of public R&D subsidies.

The performance of additional R&D activities was left to market forces and to the internal procedure of resource allocation.

A variety of alternative modes of provision of public R&D subsidies has been experienced including the use of tax credits, or specific allocations, whether they take into account the levels of R&D activities carried out by firms or their rate of increase. The recent introduction of the patent box has introduced the further distinction between R&D subsidies and patent subsidies, i.e. ex ante and ex-post subsidies: the former support the appropriation of the output of the knowledge generation function, the former its prime input such as R&D activities (Bloom, Griffith, Van Reenen, 2002). A large literature has explored the effects of these alternatives in terms of additional flows of R&D activities and patents. Much attention has been paid to the identification of the actual levels of "losses" stemming from the limited appropriability of knowledge and to identify the types of research costs that can be subsidized (Zúñiga-Vicente, Alonso-Borrego, Forcadell, Galán, 2014; Czarnitzki and Lopes-Bento, 2014)[4].

In the Arrovian market failure approach, once the public subsidies balance the losses stemming from the limited appropriability and the missing revenues are compensated by the reduction of R&D costs, firms are expected to allocate the correct amount of resources to the generation of knowledge (Guellec, van Pottelsberghe de La Potterie, 2003; Huergo,

[4] The European Union has implemented the notion of '*net extra costs*' i.e. "the difference between the expected net present values of the aided project or activity and a viable counterfactual investment that the beneficiary would have carried out in the absence of aid." (EU, 2014, pp. 7). The European Union uses the notion of extra-cost as a yardstick to quantify the appropriate amount of public subsidies and to limit the risk of undermining perfect competition: "Where it is shown, for example by means of internal company documents, that the aid beneficiary faces a clear choice between carrying out either an aided project or an alternative one without aid, the aid will be considered to be limited to the minimum only if its amount does not exceed the net extra costs of implementing the activities concerned, compared to the counterfactual project that would be carried out in the absence of aid. In order to establish the net extra costs, the Commission will compare the expected net present values of the investment in the aided project and the counterfactual project, account being taken of the probabilities of different business scenarios occurring" (EU, 2014, p.20).

Trenado, Ubierna, 2016; Henningsen, Hægeland, Møen, 2015; Becker, 2015).

The literature has also explored the effects of public subsidies and tax incentives to R&D activities in terms of increased output and productivity trying to assess whether their provision was actually able to compensate for the asserted knowledge market failure (Klette, Møen, Griliches, 2000; Hall Van Reenen 2000; D'Andria, Pontikakis, Skonieczna, 2018).

The empirical evidence suggests that public subsidies trigger a limited increase of actual R&D activities performed by recipients: the increase of R&D activities performed by recipients is lower than the actual levels of R&D subsidies received by firms. The issue of a crowing out effect has been identified and the need to assess carefully the actual additionality of R&D subsidies has becoming more and more evident (Marino, Lhuillery, Parrotta, Sala, 2016).

The additionality of public R&D subsidies is measured by the ratio of the public subsidy to the value of the additional R&D activities actually carried out. The empirical evidence shows that automatic public subsidies granted to R&D activities performed by private firms yield only a limited increase of the R&D actually carried out (Clarysse, Wright, Mustar, 2009). A large literature confirms that an important share of public subsidies substitutes internal funds with a crowding out effect (Busom, 2000; David, Hall, Toole, 2000).

The rationale of the provision of public subsidies to R&D activities carried out by firms needs to be reconsidered. The assessment of the empirical evidence depends upon the rationale and the goals of the public subsidy. The low levels of current additionality are not a signal of opportunistic crowding out behavior of recipient firms. The provision of public subsidies is aimed at compensating firms for the losses stemming from the limited appropriability of knowledge. The large and systematic evidence about the substitution of private resource with public ones to perform R&D activities by recipient firms is fully consistent with the goal of a public policy aimed at reducing the costs of R&D activities, but not with the goal to increasing the levels of R&D activities beyond their "equilibrium" levels.

The issue of the low additionality of public subsidies to R&D becomes critical as soon as the positive effects of R&D activities in terms of synchronic knowledge externalities are taken into account. R&D subsidies, in fact, benefit not only the recipient firm that is compensated of the negative effects of the limited appropriability of knowledge, but the whole system provided that the subsidies yield positive effects in terms of additional volumes of R&D activities and hence additional flows of spillover and consequent knowledge externalities that support the recombinant generation of new knowledge in the long term.

The issue of the additionality of public subsidies to R&D becomes even stronger as soon as the positive effects of the limited exhaustibility of knowledge in terms of diachronic knowledge externalities are taken into account. The actual increase of R&D activities at time t yields positive effects at the system level in terms of additional flows of spillover and consequent knowledge externalities that last for a long period of time as the new additional flows of R&D activities contribute the size of the stock of quasi-public knowledge that yields long lasting knowledge externalities that make possible to generate new additional knowledge at costs below equilibrium with positive effects on total factor productivity.

PUBLIC R&D SUBSIDIES AND THE LEVELS OF R&D ACTIVITIES. THE DERIVED DEMAND FOR KNOWLEDGE AND R&D

The advances of the economics of knowledge, namely the introduction of the technology production function and the knowledge generation function, provide the tools to analyze the effects of public R&D subsidies on the demand for knowledge (Antonelli and David, 2016).

The joint analysis of the role of knowledge as an input in the production of all the other goods, implemented by the technology production function, and as an output of the knowledge generation function enables to frame the exploration of the determinants of the effects of public R&D subsidies on the amount of knowledge used as an input downstream and an output upstream using the derived demand methodology.

The demand for knowledge in downstream activities can be studied as the derived demand of the stock of knowledge in the technology production function. The analysis of the demand for knowledge by downstream users in turn enables to study the determinants of the demand for R&D activities by upstream knowledge producers. Let us make the necessary steps.

The technology production function can be formalized as it follows:

(1) $Y = K^a L^b TK^c$

where Y measures output in value added is the product of the quantity Q_Y and its price P_Y, K the stock of capital, L labor and TK the stock of knowledge capital; a, b, c are the respective output elasticity of the production factors K, L and TK.

The cost equation is standard:

(2) $TC_Y = wL + rK + sTK$

where w is the cost of labor, r the cost of capital and s the cost of accessing and using the stock of knowledge at time t.

The knowledge generation function, in the standard Cobb-Douglas specification, and the knowledge cost equation are:

(3) $KN = R\&D^{\alpha}\, TK_{(t-1)}{}^{1-\alpha}$
(4) $TC_{KN} = zR\&D + vTK_{(t-1)}$

where KN stands for the flow of knowledge output, R&D for the internal research, learning and development activities and $TK_{(t-1)}$, for the stock of quasi-public knowledge (at time t-1), with their respective output elasticity α and 1-α. Both R&D and $TK_{(t-1)}$ have a cost. The cost z measures the costs of research and learning activities; the cost v measures the cost of accessing to and using the stock of quasi-public knowledge.

Public subsidies help reducing the cost of R&D activities. Their effect in terms of actual increase of the amount of knowledge output and of the actual increase of R&D activities carried out by recipient firms depends upon the demand of the stock of knowledge that can be easily derived from the technology production function (See eq.1) and the demand for R&D activities that can be derived from the knowledge generation function (See eq.3).

The equilibrium level of the derived demand of the stock of knowledge the output of the knowledge generation function (see eq. 3) is determined by the value of its marginal product, as an input into the technology production function, and its cost (see eq.1):

(5) $dY/dTK = Y/TK \; P_Y \; c = s$

According to eq. 5, the derived demand for the stock of knowledge, with respect to time, is determined by the output elasticity of the stock of knowledge (c) in the technology production function, the price (P_Y) of the product Y and the cost (s) of the access to and the use of the stock of technological knowledge. The cost of the additional stock of knowledge is endogenous as it depends on the knowledge generation function.

The reduction of the cost of R&D activities z affects the knowledge generation function (see eq. 3) and helps reducing the costs of the flow of knowledge output (KN) with positive effects on the cost (s) of the stock of knowledge (TK) that enters the technology production function (see eq. 1). The average cost of Y is consequently reduced.

The extent to which the reduction of R&D costs -triggered by R&D subsidies- affects the actual increase of R&D expenditures depends upon four factors: i) the market form of the product market; ii) the appropriability conditions in the knowledge markets; iii) the relative size of the subsidy itself; iv) the rates of growth of recipient firms. Let us analyze them in turn.

The market form of the product market Y affects the actual reduction of the price (P_Y) of the product Y triggered by the subsidy. The closer is the market to competitive conditions and hence the price to the actual product cost, and the smaller is the reduction of P_Y -triggered by the subsidy- hence the smaller is the slope of the derived demand for the stock of quasi-public knowledge.

The augmented levels of the stock of knowledge (dTK) triggered by the reduction of its costs coincide with the flow of knowledge generated upstream in the knowledge generation function. The inclusion of the equilibrium conditions of the demand for R&D activities derived from the knowledge generation function completes the analysis:

(6) $dKN/dR\&D= KN/R\&D \; P_{KN} \; \alpha = z$

For each given level of the demand for the stock of knowledge, the provision of a public subsidy affects the demand for R&D activities that in turn depends upon its price (P_{KN}) in turn shaped the levels of knowledge appropriability.

The smaller is the appropriability of knowledge in the markets of knowledge and -hence the flatter its shape-, and the larger - for given levels of the output elasticity of R&D activities in the knowledge generation function- the effect of the R&D subsidy that reduce the levels of z, on the actual levels of R&D activities carried out by the recipient.

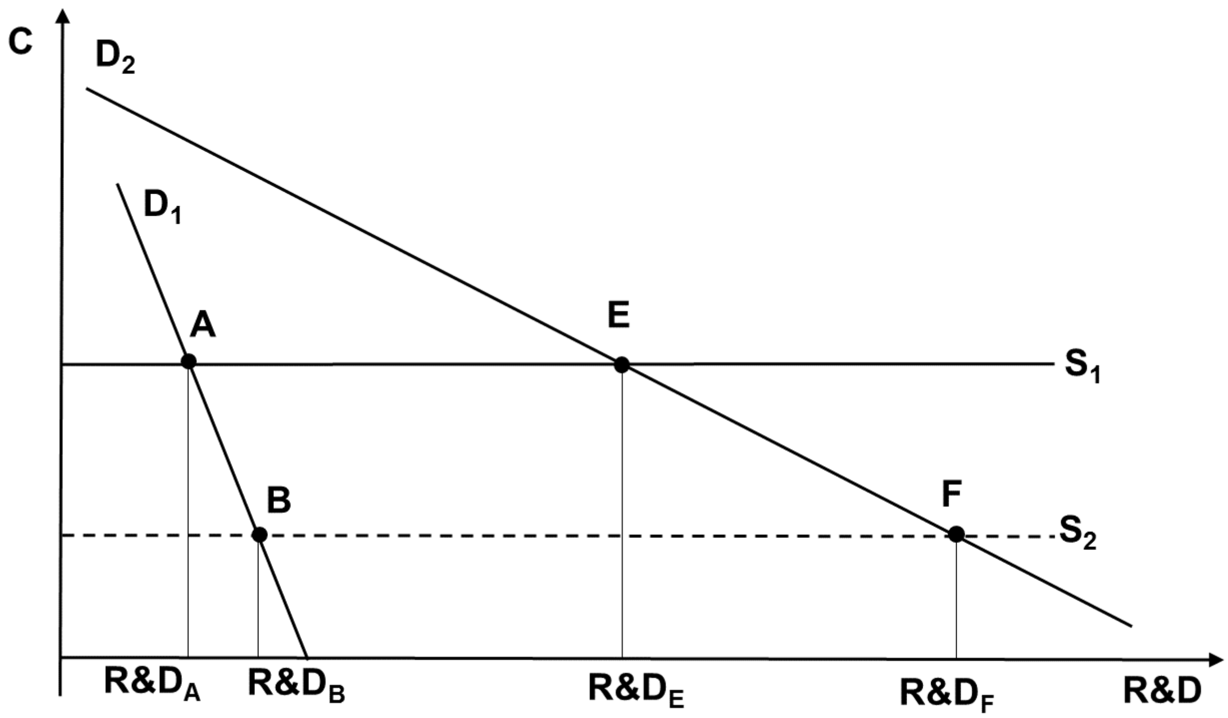
On the opposite, the larger is the appropriability of knowledge in the markets for knowledge, and the larger is the slope of the derived demand for R&D activities and hence the steeper is its shape and the smaller the effect of a reduction of R&D costs on the levels of R&D activities performed by recipient firms.

Figure 6.1 synthetizes the bulk of the argument.

INSERT FIGURE 6.1 ABOUT HERE
Public subsidies reduce the costs of R&D activities: the supply curve of knowledge shifts from S_1 to S_2. Their effect in terms of actual increase of R&D activities carried out by recipient firms depends upon the combined effects of the slope of the derived demand for the stock of knowledge and

the slope of the derived demand for R&D activities. The closer to monopolistic conditions are both product and knowledge markets and the larger is the slope of the derived demand for knowledge as much as the slope of the derived demand for R&D (see D_1), and the smaller are the additionality levels <1: R&D expenditures increase from $R\&D_A$ to $R\&D_B$. In competitive product and knowledge markets the slope of the derived demands is small (see D_2), additionality levels are larger and >1: R&D expenditures increase from $R\&D_E$ to $R\&D_F$.

FIGURE 6.1 EFFECTS OF R&D SUBSIDIES ON R&D LEVELS



Let us now consider the well-known effects of demand elasticity. For given slopes of the derived demand for the stock of knowledge and of the related derived demand for R&D, the effects of subsidies, in terms of increased levels of R&D, depend upon the levels of R&D costs with respect to the derived demand. The increase of R&D expenditures triggered by R&D subsidies is larger, the larger is the price elasticity on the derived demand. Subsidies that reduce R&D costs in the portion of the derived demand with $\varepsilon>1$ will trigger a larger rate of R&D increase than subsidies that affect the reduction of R&D costs where -on the derived demand curve- $\varepsilon<1$. For a given level of subsidy, the smaller is its share with respect to R&D costs and the closer it is to the intercept on the vertical axis of the derived demand, the larger are the effects in terms of actual rate of increase of R&D activities. Subsidies that represent a small share of high quality research projects with high costs that insist on the elastic portions of the derived demand for R&D activities are likely to stir a large increase of R&D activities.

Finally, it seems clear that the larger the rate of growth of recipient firms and the larger the rate of increase of R&D activities, hence the easier to meet the strong additionality requirement that can be matched even without the increase of the ratio of R&D expenditures to sales. In a dynamic setting the strong additionality requirement can be easily met by firms that enjoy rapid rates of growth.

Public subsidies aimed at increasing the actual size of the stock of quasi-public knowledge and hence the current level of R&D expenditures should be assigned to firms that are active in competitive product markets with low barriers to entry and imitation, to R&D activities that are likely to deliver knowledge outputs with low levels of appropriability and radical research projects with large R&D costs.

The introduction of a strong additionality requirement according to which firms can benefit from public R&D subsidies only if they are able to increase the amount of R&D activities by an amount at least equal to that of the public subsidy triggers a self-selection mechanism by means of which the possible recipients operate in competitive product markets with low barriers to entry, knowledge markets with low levels of appropriability, undertake R&D activities with high costs and enjoy fast rates of growth. Low growth firms that enjoy barriers to entry low appropriability would be able to meet the strong additionality requirement only if the research project is actually promising so as to justify the actual increase of R&D activities beyond the levels of the public subsidy. The strong additionality requirement would sort out firms that undertake research projects that are less likely to yield important knowledge externalities to the rest of the system.

A NEW GOAL FOR R&D SUBSIDIES: FROM R&D COST REDUCING TO KNOWLEDGE OUTPUT INCREASING

The analytical framework elaborated so far enables to articulate a clear policy procedure. Public R&D subsidies can be provided to private firms that undertake innovative activities only if they are able to meet the strong constraint of an additionality level >1. The additionality level is > 1 when the flow of additional R&D activities (ΔR&D) carried out by the recipient of a subsidy is larger than the amount of the subsidy (SUB) itself:

(7) ADD= ΔR&D/SUB; where ADD >1 when ΔR&D>SUB.

The identification and implementation of the goal of an additionality level >1 has several positive effects:

i) it helps increasing the rate of generation of knowledge and hence the rate of accumulation of the stock of quasi-public knowledge that supports with increasing and persistent pecuniary knowledge externalities the recombinant generation of new knowledge;

ii) it reduces the costs of R&D activities and hence compensate firms that carry out innovative activities for the limited appropriability of the new knowledge;

iii) it helps screening and sorting recipient firms that operate in competitive product markets with low levels of knowledge appropriability;

iv) it favors the allocation of public subsidies to firms that engage in high-quality R&D projects.

The combination of these four layers is most important. The strong additionality requirement, according to which the ratio of the rate of increase of R&D activities to the subsidy must be >1, helps directing the public support towards recipients that are active in competitive product markets with low barriers to entry and experience fast rates of growth and are engaged in high-quality R&D activities.

Firms that are not able ex-post to certify the compliance with the strong additionality requirement should pay back the excess subsidy.

In so doing the strong additionality requirement helps the identification of the types of firms, R&D activities and knowledge exploitation processes that are most likely to contribute the accumulation of a quasi-public stock of knowledge and hence the rate of generation of new knowledge and of introduction of further innovations.

Stronger additionality requirements act as a self-selection mechanism by means of which only firms active in competitive markets with lower levels of knowledge appropriability and fast rates of growth and high quality of their research activity, that contribute more to the accumulation of the stock of quasi-public knowledge, can actually comply with the new constraints to access the public subsidies to their R&D activities.

6.3 THE PUBLIC SUPPORT TO KNOWLEDGE EXPLOITATION

Patents had been introduced first in the late XV century by the Republic of Venice to attract craftsmen from the Middle East to Venice. The economics of knowledge rationalized, ex-post, their role as an effective institutional remedy to reduce the negative effects of the limited appropriability of knowledge. Patents and trade-marks enable knowledge holders to reduce the risks stemming from the limited appropriability of knowledge. Patents and trade-marks provide the foundations for the monopolistic exploitation of technological and commercial knowledge. Patents and trade-marks provide the institutional foundations for the working of knowledge quasi-markets. Without patents and trade-marks knowledge trade would be impeded by the uncontrolled leakage of knowledge. Patents and trade-marks enable to valorize knowledge not only by means of knowledge transactions, but also by means of the embodiment of intellectual property rights in capital by means of the creation of knowledge intensive equity. Patents are indispensable not only to increase the appropriability of knowledge and its exploitability, but also to favor the dissemination of knowledge. Patents avoid or reduce the systematic use of secrecy that would become the unique tool for knowledge holders to increase the chances to retain the flows of rents stemming from knowledge. Moreover, patents are a powerful mechanism that makes the advances of the knowledge frontier publicly known: patents provide information to the system.

The current regime of intellectual property rights is based upon homogeneous patents characterized by absolute exclusivity.

There is no differentiation of patents across types of knowledge and their use. The very same patent applies to the full spectrum of types of knowledge and possible uses. Patent holders have the right to exclude third parties from the unauthorized use of their patents. Patent holders may decide to license their patents and receive a royalty from the users, but they are not obliged to license. They may retain the exclusive right to use the knowledge until the patent expires.

The solution of the appropriability trade-off is at the heart of the long-term viability of the knowledge growth regime. On the one hand it is in fact clear that patents are indispensable to increase the appropriability of knowledge, on the other, however, patents reduce the pace of the recombinant generation of new knowledge as they limit the access to indispensable inputs. All changes in the intellectual property right regime modify the effects of the appropriability trade-off. The augmented levels of knowledge appropriability provided by the strengthening of the intellectual property rights implemented since the last decade of the XX century play a central role in the exploitation and valorization of knowledge as capital (Orsi, and Coriat, 2006).

The knowledge growth regime suffers the intrinsic contradiction between the conditions of the generation of technological knowledge and the conditions of its exploitation (Pagano, 2014; Pagano and Rossi, 2009).

As Pagano (2014: 1416) notes: “Rather than preventing a tragedy of commons, their private ownership is instead likely to produce an anti-commons tragedy (Heller and Eisemberg, 1998). The fields of knowledge are not subject to overcrowding. By contrast, they may be greatly damaged if they are enclosed within narrow and rigid boundaries. When the access to knowledge is severely restricted by the fields privatized by others, agents are forced to specialize in narrow fields and they are likely to suffer a dramatic squeeze of investment opportunities. In other words, an anti-commons tragedy due to over-privatization is likely to occur."

The recombinant generation of technological knowledge relies on the access and use of existing knowledge. Knowledge shares all the intrinsic characteristics of an essential facility as its use as an input is indispensable not only for the production of all the other goods -in the technology production function- but also in the generation of knowledge. Moreover, because of its limited exhaustibility, the larger is the amount of knowledge(s) each agent can access and use and the larger is the knowledge output. Specifically, knowledge output increases at a more than proportionate rate with respect to the increase in the variety of knowledge inputs. At the same time the exploitation of knowledge requires high levels of appropriability of knowledge as an output. Intellectual property rights are strictly necessary to enforce knowledge appropriability. The un-limited access to all existing knowledge limits the incentives to its generation as well as the viability of its funding.

A system with no intellectual property rights would suffer the negative consequences of the lack of incentives: patents are necessary. At the same time patents limit the access to existing knowledge as an indispensable input in the recombinant generation of new knowledge (Boldrin, Levine, 2002 and 2013). The over-privatization of knowledge curbs the rates of generation of new knowledge.

The exclusivity of the current IPR regime has been criticized for the high risks of anticommons (Heller and Eisenberg (1998). The barriers and delays to the use of proprietary knowledge stemming from exclusive patents increase knowledge appropriability and hence the incentives to its generation but reduce the general efficiency of the generation of knowledge. According to Scotchmer (1999; 2004; 2010) the negative effects of the exclusivity of patents are especially evident when new knowledge builds upon the previous knowledge vintage. Exclusive IPR induce firms and inventors to duplicate research effort and to invent around. In the extreme cases, exclusive patents impede the use of an essential facility that cannot be reproduced and stop the advance of technological knowledge (Laitner and Stolyarov, 2013). New technological knowledge, in fact, is the result of the recombination of existing knowledge: in such a context the stock of existing knowledge has all the intrinsic properties of an essential facility (Antonelli, 2007).

Current IPR together with high transaction costs in the markets for knowledge produce a fragmented knowledge landscape where owners of small complementary bits of knowledge are unable to participate in the collective effort that is needed to generate new knowledge as an output while using existing knowledge an input (David and Hall, 2006).

At the same time, it is clear that patents perform an essential role in the knowledge economy as they provide indispensable information about the progress in the frontiers of knowledge. The alternative to patents is secrecy: firms and inventors would try and keep their knowledge secret so as to reduce the risks of uncontrolled leakage. Secrecy has strong negative effects in terms of missing information about the advances of knowledge and may actually increase the amount of resources wasted in the duplication of research efforts (Bielig, 2015).

The classical argument in favor of the introduction of differentiated patents rests upon the analysis of the types of market forms in the different industries and product markets (Gilbert and Shapiro, 1990). Patent terms should be industry-specific: shorter the more intense is competition, the higher the productivity of R&D activity and the more intricate the reverse engineering (Mosel, 2011).

Yet it is clear that the very same knowledge may be relevant in a broad array of industries and many different types of knowledge are relevant within the same industry. The cases of general purpose technologies, such as ICT and biotechnologies, show how large can be the scope of some knowledge items that apply to a variety of well distinct industries with well differentiated types of competition and market structure (Bresnahan and Trajtenberg, 1995).

The literature has concentrated its attention on the optimal breadth and length of patents and has explored in depth the limits of the current levels of exclusivity calling attention of the negative effects of exclusive property rights on the generation of new knowledge characterized by high levels of cumulativity (Scotchmer, 1999, 2004, 2010; Polanki, 2007; Green and Scotchmer, 1995; O'Donogue Scotchmer and Thisse, 1998). This literature, however, has not explored the possibility of the coexistence of patents that allow different levels of exclusivity for the very same proprietary knowledge.

The differentiation of the IPR regime can be implemented by the analysis of the distinction between intra-industrial and inter-industrial spillovers and knowledge externalities. The use of patents with high levels of exclusivity to remedy the negative effects of the limited appropriability of knowledge is an effective tool to increase the amount of knowledge generated in a system in the case of intra-industrial spillovers, rather than in the case of inter-industrial spillovers. When interindustrial spillover apply, compulsory licensing with fair royalties seems to yield a superior outcome.

The positive effect of patents, in fact, consists in the impediment to the entry of imitators in the very same product market. Patents with high levels of exclusivity help contrasting the Arrovian knowledge market failure as they create a legal monopoly that enables inventors to extract the expected quasi-rents from the exploitation of their knowledge and re-establish the appropriate levels of incentives to the generation of knowledge. As far as intra-industrial spillovers are concerned, the negative consequences of patents with high levels of exclusivity, in terms of delayed use of an essential facility, are compensated by the positive effects in terms of augmented knowledge appropriability and hence incentives to its generation.

The negative consequences of exclusive patents are much stronger for inter-industrial spillovers than for intra-industrial ones. The positive effects of exclusive patents are not sufficient to compensate the negative ones. Exclusive patents, in fact, limit the use of proprietary knowledge as an input in the generation of new knowledge that applies to other product markets and have no consequences in terms of augmented knowledge appropriability and hence incentives to its generation, but strong negative effects in terms of opportunity costs for the generation of new knowledge. Because of the exclusivity of patents, the recombinant generation of new knowledge cannot access existing knowledge as an essential facility.

USER SPECIFIC PATENTS

The case of general purpose technologies and the appreciation of the intrinsic heterogeneity of the uses of knowledge together with the key distinction between intra-industrial and interindustrial spillovers enables to explore the viability of the introduction of user-specific patents. The exclusivity of a patent should vary according to its users and uses: users that declare to be non-competitors of the patentee should be enabled to access and use the proprietary knowledge with lower levels of exclusivity. Standard exclusivity should apply to their use by competitors.

The identification of the optimum level of the price of knowledge enables to implement the effective application of the liability rule to the compulsory licensing of non-exclusive patents (Reichman, 2000; Reichman and Maskus, 2005).

Compulsory licensing of non-exclusive property rights applies when potential users, active in other product markets, access proprietary knowledge only as an input for the generation of new knowledge, rather than as an input –ready to be used- in their technology production function, provided they pay a fair royalty, based upon the value of the proprietary knowledge, that includes appropriate profit margins for knowledge producers (Antonelli, 2015a and b).

The design of a differentiated IPR regime, based upon user-specific patents, enables to separate the negative effects of intraindustrial spillovers in terms of reduced incentives, from the positive effects of the knowledge externalities stemming from interindustrial spillovers.

The design of differentiated IPR in terms of exclusivity levels should be implemented according to the uses of knowledge: i) patents with weak exclusivity that should be granted to knowledge items that are used as inputs into the knowledge generation function by non-competitors; and ii) patents with strong exclusivity that can be confirmed only to knowledge items ready-to-used as inputs in the technology production function of competitors.

Inventors apply at the same time for a two layers patent for the very same knowledge. Inventors would hold for the same knowledge item: 1) an exclusive patent so as to increase the appropriability of their proprietary knowledge and impede its imitative use by competitors in their product market and 2) a non-exclusive patent with compulsory licensing that does not exclude its use by third parties that sign a non-competition declaration. Compulsory licensing entitles the patent holder to receive the payment of a royalty from the user.

The definition of a fair level of royalties is clearly crucial. The levels of the royalties define the levels of de-facto exclusivity. High level royalties imply strong de-facto exclusivity. Low level royalties imply weak de-facto exclusivity.

A fair level of royalty can be identified by the compulsory declaration of the value of patented knowledge as a part of procedure for the assignment of the patent. The procedure for patent granting should include a value declaration: the patent seeker declares the expected value of the knowledge for which the patent is requested. The value of the proprietary knowledge declared to the patent office is submitted to a specific taxation. The negative fiscal consequences of the declaration of excess values are clear: the perspective patent holder must pay relevant taxes.

The value of the proprietary knowledge provides the basis for the identification of a fair royalty that should include appropriate levels of profitability taking into account the levels of risks and the complementarity of the new knowledge with respect to the knowledge base of the patentee.

The access to non-exclusive IPR is subject to the payment of a fair royalty that can be identified on the basis of its declared value. The patent office defines the maximum level of the total royalties that can be earned. The actual definition of the royalty is left to the market place. Once the maximum level of the royalty has been earned by the patentee, knowledge is no longer proprietary and all firms can access and use it without any royalty.

The licensing contract should be made public so as to increase the transparency of the market place. Licensees can take the courts to curtail excess royalties. Patentees have the right to appeal in court licensees that do not comply with the non-competition declaration.

The strength of the differentiation of the exclusivity of IPR consists in the reduction of the negative effects of the appropriability trade-off. The access to proprietary knowledge for uses and by users that are not competitors of "inventors" for the generation of new knowledge, that does not affect the product market where inventors are based, enables to take full advantage of the positive effects of the recombinant generation of knowledge, to fasten the rate of generation of new knowledge and to reduce its costs, hence to increase total factor productivity.

The enforcement of a fair royalty enables to protect the correct levels of incentives for the generation of new knowledge and to avoid the risks of knowledge market failure without missing the opportunity to take advantage of the use of knowledge as an indispensable input in the generation of new knowledge.

The ex-ante enforcement of the proposal seems to be quite straightforward. The access to proprietary knowledge is conditional to: i) a non-competition declaration by the perspective user and ii) a value declaration by the patentee. Moreover, all the licensing contracts should be public so as to increase the transparency of the new markets for knowledge and avoid excess royalties.

Compulsory licensing for non-competitive uses of proprietary knowledge should help to implement the working of the markets for knowledge stirring both the demand for knowledge as an input and its supply by loath patentees. Much evidence confirms that the supply of proprietary knowledge to potential users in the markets for licenses is hampered by patentees that are reluctant to make their knowledge available to third parties (Geroski, 1995).

The weakness of the differentiation of the exclusivity of IPR stems from the enforcement costs that are likely to be non-negligible. The declaration of non-competition on the part of users is likely to trigger substantial litigation that add to the controversies about the boundaries of the proprietary knowledge itself (Sterlacchini, 2016, Cremers, 2017). The general purpose nature of knowledge entails that it is not straightforward to distinguish knowledge "by uses" and by products of application. The boundaries among product markets are not easy to identify and grey zones may exist, with negative consequences in terms of reasons for controversy and litigations (Bloom, Schankerman, Van Reenen, 2013). The enforcement of the new non-exclusive IPR would share the same problems faced by competition policy enforcement where the assessment of the extension of the product market plays a crucial role (Stiglitz, 2008 and 2017). Yet, although the enforcement costs of competition policy are quite relevant, there is no doubt that their implementation yields positive effects at the system level.

Quite the same argument seems to apply to the introduction of the two-layers IPR regime. The joint assessment of the weaknesses and strengths of the proposal suggests that the net positive effects are larger. The advantages of the reduced exclusivity of property rights and the consequent access to the existing stock of knowledge as an input in the generation of new knowledge is likely to trigger significant benefits at the system level in terms of increased total factor productivity levels that largely offset enforcement costs.

The costs of litigations about the maximum level of the fair royalty may be regarded as a major source of weakness. The risks of legal actions by licensee however should prevent patentees from imposing excess royalties. The transparency of the licensing agreements including the levels of royalties should help to enforce the working of the market place.

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7. CONCLUSIONS

THE CONCLUSIONS SUMMARIZE THE FOUNDING STONES OF THE ANALYTICAL FRAMEWORK IMPLEMENTED BY THE BOOK GRAFTING OF THE TOOLS ELABORATED BY THE ECONOMICS OF KNOWLEDGE AND THE LEGACY OF JOSEPH SCHUMPETER. IT SYNTHETIZES THE MAIN RESULTS OF THE ANALYIS: i) THE NEW STRUCTURE OF ADVANCED ECONOMIES, ii) THE SHIFT AWAY FROM THE CORPORATE GROWTH REGIME, iii) THE EMERGENCE AND CONSOLIDATION OF THE NEW KNOWLEDGE GROWTH REGIME WHERE iv) KNOWLEDGE IS AT THE SAME TIME THE PRIME INPUT AND OUTPUT. IT EMPHASISES THE LIMITS OF THE NEW KNOWLEDGE GROWTH REGIME, RAISED BY THE ROLE OF FINANCE, INCOME INEQUALITY AND INTELLECTUAL PROPERTY RIGHTS. IT RECOMMENDS A NEW KNOWLEDGE POLICY BASED UPON AN OPEN TECHNOLOGY APPROACH THAT BUILDS UPON NON-EXCLUSIVE INTELLECTUAL PROPERTY RIGHTS AND R&D SUBSIDIES WITH STRONG ADDITIONALITY.

KEY WORDS: INCOME INEQUALITY; OPEN TECHNOLOGY APPROACH; NON-EXCLUSIVE PROPERTY RIGHTS; ADDITIONALITY REQUIREMENTS.

The new economics of knowledge is indispensable to grasp the working of the new knowledge economy. The analysis of knowledge as an economic good is a fertile and promising field of investigation that can yield important results in the analysis not only of the generation and exploitation of knowledge but also in the analysis the working of a system based upon the generation and exploitation of knowledge.

Knowledge has several idiosyncratic properties that deserve all to be identified and explored in detail. Their implications and consequences are most important and need to be considered all together. The economic literature has paid much attention to a sub set of the broader bundle of knowledge idiosyncratic features. Attention has been attracted primarily if not exclusively by its limited appropriability, its non-rivalry in use, the sharp difference between generation and reproduction costs. The selection of these features has led to a substantial consensus about the limits of knowledge as an economic good and their consequences in terms of market failure.

The identification of the limited exhaustibility as a key intrinsic property of knowledge enables to modify the standard frame according to which knowledge has many shortcomings and weaknesses as an economic good. Actually the 'discovery' of the limited exhaustibility of knowledge seems to uncover unexpected merits and strengths of knowledge as an economic good.

The distinction between intra-industrial and inter-industrial spillovers enables to enrich the analysis of the effects of the limited appropriability of knowledge. Intra-industrial spillovers engender imitation externalities that consist in the direct access of competitors and rivals, in the same product market, to proprietary knowledge ready-to-be-used as an input into their technology production function. Imitation engenders the entry of new suppliers and the consequent reduction of the prices of the innovated goods and the fall of the price-cost-margins of inventors. The traditional Schumpeterian argument according to which monopolistic market power for innovated goods is transient and yet positive in terms of welfare is based upon intra-industrial spillovers and applies to imitation externalities. Monopolistic extra-profits are doomed to decline because of imitation and yet yield strong incentives to the generation of new knowledge. The Arrovian postulate, according to which the limited appropriability of knowledge is at the origin of a major failure of competitive markets for the lack of incentives to the generation of knowledge applies clearly to imitation externalities.

Knowledge externalities take place when proprietary knowledge spills outside the industry and is not ready-to-be-used as such but is used by recipients as an input for the recombinant generation of new knowledge. Knowledge externalities augment the amount of knowledge that can be produced by the knowledge generation function with a given budget. Knowledge externalities take place when and if the cost of accessing and using the stock of quasi-public knowledge that characterizes economic systems, is lower than the costs of its regeneration. Knowledge externalities exert three distinct effects: i) direct positive effects in the knowledge generation function as they enable to increase the amount of knowledge that can be produced with a given budget; ii) indirect positive effects as the cheaper knowledge generated upstream in the knowledge generation function enters the downstream technology production function and enables to produce a larger amount of output with a given budget; iii) negligible negative effects on the price of goods produced and sold in the product market of the inventor.

The Arrovian postulate does not apply to inter-industrial spillovers and knowledge externalities because there is not the risk of market failure stemming from the fall of price of products within the industry of inventors, with the well-known consequences in terms of missing incentives and undersupply of knowledge. The positive effects of inter-industrial spillovers, instead, are very strong in terms of reduced knowledge costs.

The appreciation of the limited exhaustibility of knowledge coupled with its limited appropriability enables to understand that knowledge as an economic good is "better" rather "worst" than standard goods because of its powerful effects on the generation of knowledge and its effects on the creative response of firms to out-of-equilibrium conditions.

Knowledge is at the same time an input and an output of the generation of knowledge is an explicit economic activity. The generation of knowledge in fact consists in the recombination of existing knowledge items. The access to knowledge generated by third parties plays a central role in the recombinant process. Existing knowledge is an essential facility. Knowledge spilling from third parties cumulates into a stock of quasi-public knowledge that firms try and use as an input. Pecuniary knowledge externalities stem from the difference between reproduction and access costs. The positive effects of knowledge externalities consist in the reduction of knowledge costs and hence in the downward shift of the knowledge supply schedule. The negative effects in terms of reduction of the price of innovated goods in the original product market, and hence missing appropriation and fall of incentives, are negligible. The analysis of the appropriability trade-off shows that the positive effects of pecuniary knowledge externalities in terms of above equilibrium supply of knowledge and below-equilibrium knowledge prices are far larger than their negative ones.

Within the Schumpeterian framework of the creative response, the conditions for the generation, use and exploitation of knowledge are crucial to support the innovative capability of an economic system. Knowledge is a special good that may be actually "better" rather than "worst" than standard economic goods.

When its generation and exploitation take place in highly qualified and contingent institutional and economic contexts it enables to achieve economic performances well above equilibrium levels. The limited exhaustibility of knowledge enables its accumulation with major implications for its generation. The cost of knowledge is far below the equilibrium cost of any standard good. As a consequence, productivity and output growth depend upon the conditions in which the difference between knowledge equilibrium cost and actual cost is actually exploited. When the generation, use and exploitation of knowledge take place in highly qualified institutional and economic contexts, knowledge costs fall below equilibrium levels and enable firms to extract rents and economic systems to experience output levels that are above the equilibrium levels.

When its generation and exploitation do not take place in appropriate contexts, instead, and pecuniary knowledge externalities vanish, the case for market failure applies. Economic systems are not able to take advantage of the opportunities provided by knowledge as an economic good that might have been "better" than standard economic goods and are trapped into equilibrium conditions.

The characteristics of the system into which the generation, accumulation and exploitation of knowledge take place in terms of quality of knowledge governance mechanisms are crucial to take advantage of the potentialities of knowledge.

The new understanding of the dynamics of increasing returns stemming from the limited exhaustibility of knowledge and its effects in terms of accumulation of a long lasting stock of knowledge that is indispensable for the generation of new knowledge enables to grasp the working of advanced economic systems where knowledge is the central economic good.

The emergence of the new knowledge economy that has been taking place since the end of the XX century and the first decades of the XXI century has been driven by the: i) increasing globalization of product markets; ii) increasing role and globalization of financial services; iii) continuing reduction of the share of GDP produced by manufacturing industries in favor of the share of GDP produced by service industries; iv) introduction of directed technological change biased towards knowledge intensive technologies; v) exploitation of knowledge capitalized as a financial asset; vi) decline of the fixed capital intensity of the production processes and the consequent reduction of investments; vii) apparent reduction of the rates of growth of output and productivity; viii) increase in the share of revenue paid to knowledge capital that ix) parallels the segmentation of labor markets with increasing levels of income and wealth inequality.

This interpretation contrasts the argument according to which western economies would be facing a secular decline of productivity growth determined not only by structural and social unbalances –headwinds- at the system level but also by the slowdown of technological change.

The analysis carried out through this book has shown that the trends towards the decline of output and productivity growth are more apparent than real. Current economic and statistical procedures are unable to cope with the structural change of advanced economies away from the corporate growth regime into the knowledge growth regime and the central role played in this context by the capitalization of knowledge as a financial asset. The evidence is influenced by the statistical mis-measurement of the effects of the capitalization of knowledge as an output that adds to the mis-measurement problems associate with the prices of high tech products.

This book has articulated the hypothesis that the economic system of advanced countries is experiencing not only the consequences of the introduction of radical technological changes, but also and primarily a radical transformation of its Schumpeterian growth regime i.e. the mechanisms that implement the coordination and organization at the system level of the generation, exploitation and use of knowledge in societies and make the creative response possible. The new role of knowledge as the key output and input, the central product as well as the central production factor and the new modes of organizing its generation, use and exploitation identifies the transition to a new Schumpeterian growth regime.

The mechanisms by means of which economic systems cope with the properties of knowledge as an economic good -its limited appropriability, exhaustibility and tradability- and the idiosyncratic, systemic and highly contingent conditions that shape its generation, use and exploitation and enable the creative reaction of firms caught in out-of-equilibrium conditions, are in fact key to grasping the types of Schumpeterian growth regimes at work.

The notion of Schumpeterian growth regime enables to analyze the changing sets of systemic conditions at the level of firms, final and intermediary product markets, financial and labor markets, and the macroeconomic and institutional contexts that shape: i) the out-of-equilibrium conditions that stir the reaction of firms; ii) the mechanisms of knowledge governance that support the generation, exploitation and accumulation of knowledge; iii) the re-production of the endogenous knowledge externalities; iv) upon which is based the capability of economic systems to support the creative reaction and the consequent introduction of technological and structural change.

The Schumpeterian growth regime is an indispensable frame necessary to understanding the dual relationship between the working of the system and the mechanisms of generation, exploitation and accumulation of technological knowledge. Schumpeterian growth regimes show, in fact, how the system shapes the creative reaction and the generation, exploitation and accumulation of technological knowledge, and how the mechanisms of generation, exploitation and accumulation of knowledge in turn shape the structure and the dynamics of the system.

In the new Schumpeterian knowledge growth regime, knowledge is not only the central input and output of the knowledge economy, but also as the critical component of total capital. The capitalization of knowledge emerges as the distinctive element of the new growth regime. The analysis of the laws of generation, exploitation and valorization of knowledge is indispensable to understanding the working of the knowledge growth regime at the aggregate level.

The idiosyncratic characteristics of knowledge as an economic good are at the origin of the growth of total factor productivity and output. The better is the quality of the knowledge governance mechanisms that reduce the levels of knowledge absorption cost and the larger is the current generation of knowledge and the larger the knowledge stock, the lower is cost of knowledge as an output of the knowledge generation function, and as an input in the technology production function, and the larger are the chances that the response of firms to out-of-equilibrium conditions is creative and consequently the larger are output and productivity levels.

The analysis of the capitalization of knowledge and of the central role of financial markets, carried out through this book, should enable to grasp the actual dynamics of growth of output and productivity at the aggregate level that takes place in the knowledge growth regime.

Finally, the increasing role of knowledge as the base of the international specialization of advanced countries exposed to the globalization of product and factor markets has the direct consequence to expose standard labor to the consequences of the international competition from low wage countries while the employment opportunities of creative workers are relatively protected by the size and quality of the stock of quasi public knowledge as well by the quality of the mechanisms of knowledge governance rooted in the economic systems of advanced countries. The pervasive role of knowledge as the prime input and output of the knowledge growth regime is the prime cause of the increasing levels of wage, wealth and income inequality.

The shift away from the corporate growth regime to the knowledge growth regime can be regarded as the outcome of the creative response implemented by advanced countries to cope with the twin globalization. The twin globalization of product and financial markets undermined the viability of the corporate growth regime on two counts. First, the globalization of product markets exposed the manufacturing industry of advanced countries to the winning competitive pressure of the industrial products manufactured, often under the control of global corporations based in advanced countries, in low wage countries. Second, the globalization of financial markets gave industrializing countries the access to credit at low costs, often provided by global financial institutions based in advanced countries, that questioned the specialization of advanced countries based upon the relative abundance of capital. The decline of the corporate growth regime stirred the search and eventual implementation of a new specialization based upon the relative abundance of the stock of technological and scientific knowledge embedded in the structure of advanced economic countries. The emergence of the knowledge growth regime that puts the generation and exploitation of knowledge at the core of its participation to the international division of labor, can be regarded as the outcome of the collective creative response of advanced countries to cope with the crisis and decline of the corporate growth regime. The strong increase of the share of intangible assets in the total asset value of the S&P 500 firms and the decline of the share of fixed capital seems to confirm the important role of the knowledge intensive and fixed capital saving bias of technological change.

The increasing levels of income inequality associated with the transition to the knowledge growth regime are the results of: i) the segmentation of the labor markets into two distinct sections. In the markets for standard labor, wages decline because of the dynamics of factor costs equalization. In the markets for creative labor, on the opposite, wages increase because of the sharp increase of the derived demand for knowledge triggered by the knowledge intensive direction of technological change; 2) the new mechanisms of knowledge exploitation based upon its capitalization together with the knowledge intensive direction of technological change that increases the share of income paid to the possessors of knowledge; rather than to creative labor that is indispensable to both its generation and application to the production of all the other goods.

The appreciation of the limited exhaustibility of knowledge and its effects on the radical difference in the outcomes of the appropriability trade-off between intra-industrial and inter-industrial spillovers and consequently between imitation and knowledge externalities has important implications not only for the economic analysis of the knowledge economy but also for economic policy. The discovery of the limited exhaustibility of knowledge in fact has important consequences for the current regime of IPR and the rationale behind the provision of public subsidies to R&D activities funded by firms.

It seems necessary to overcome the limits of the homogeneous patent system based on the exclusivity of the knowledge property assigned by patents and to move towards a differentiated regime of IPR based upon user specific patents.

It seems necessary to limit the application of current exclusive patents to intra-industrial spillovers. Patents holders retain the right to exclude competitors and rivals from the uncontrolled use of their proprietary knowledge ready-to-be used in their technology production functions.

The use of proprietary knowledge as an input in the recombinant generation of new knowledge should not be impeded. Compulsory licensing should apply for all uses of proprietary knowledge to generate new technological knowledge and introduce innovations in other industries and other product markets. The liability rule can apply effectively in this context. The definition of fair royalties can be implemented with the provision of detailed information on R&D costs incurred by inventors. Non rival users have the right to use proprietary knowledge as an input, provided they inform patent holders and pay them a fair royalty.

The systematic and generalized provision of exclusive IPR and automatic public subsidies to the generation of all kinds of knowledge, irrespective of their actual levels of exhaustibility and appropriability should be reconsidered. The heterogeneity of knowledge in terms of varying levels of exhaustibility and appropriability should be operationalized to design a differentiated set of knowledge policies.

The differentiation of IPR with the introduction of user-specific patents with varying terms and levels of exclusivity according to the use of proprietary knowledge spilling –whether as an input in the technology production function of competitors in the same product markets, or an input in the knowledge generation function of firms active in other product markets-should be implemented so as to take into account the twin positive and negative effects of knowledge spillovers. The introduction for the very same knowledge item of non-exclusive patents for non-competitive uses of the proprietary knowledge next to exclusive patents for the proprietary knowledge used to compete in the same product market can help fostering the pace of technological change and the viability of the knowledge growth regime.

The identification of the long term effects of the limited exhaustibility of knowledge calls for the implementation of a new framework for knowledge policy aimed at increasing the additionality of R&D subsidies so as to foster the rates of accumulation of the stock of quasi-public knowledge.

The primary goal of the public subsidies to R&D activities, provided to private firms that undertake R&D activities, is no longer the reduction of R&D costs to compensate for the missing revenue caused by the limited appropriability of knowledge but the increase of the flows of knowledge generated in the system and consequently the rates of accumulation of the stock of quasi-public knowledge that build up because of joint effect of the limited exclusivity and appropriability of knowledge and yields crucial pecuniary knowledge externalities.

The strong additionality requirement has positive effects on the system both synchronically and diachronically. At each point in time the strong additionality requirement acts as a sorting mechanism that select recipients that experience fast rates of growth, perform high quality research projects that yield large spillovers that help increasing consumer’s surplus in the downstream product markets. At the same time the augmented flows of R&D activities and knowledge generated increase the rates of accumulation of the stock of quasi-public knowledge with long-lasting positive effects in terms of knowledge externalities.

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